FIVE YEARS QUESTIONS AND ANSWERS

NATIONAL ASSOCIATION OF STATIONARY ENGINEERS

VOLUME II

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FOREWORD

This volume contains the Questions and Answers of the course carried on by the National Educational Committees of the National Association of Stationary Engineers during the years 1902 to 1906, inclusive.

It is practically volume 2 of the work so widely and favorably known as the "Five Years' Questions and Answers," published by the National Association of Stationary Engineers in 1902.

The object of this volume is to present information for engineers in such a manner as will convey the necessary information clearly and yet concisely.

There has been added to the regular educational work, a series of tables which of themselves form a modest work of reference.

This volume was compiled by the National Educational Committee for 1907–1908. Messrs. Chas. W. Naylor, Otto Luhr and F. J. Roos, all of Chicago, and members of Illinois Nos. 28, 38 and 2, respectively.

NATIONAL ASSOCIATION OF STATIONARY ENGINEERS.

QUESTIONS AND ANSWERS

1902-1906.

Engines.

Q. 1. Describe, in a general way, a simple slide-valve engine.

Ans. 1. A simple slide valve engine has three port openings, one for exhaust steam, and two for the admission of steam to each end of the cylinder. The slide valve is so fitted, then when at the center of its travel, it covers both steam and exhaust ports; it is actuated by means of a valve rod and an eccentric rod driven by an eccentric, the latter being mounted upon the engine shaft. The motion of the eccentric communicated to the valve moves the latter so that when steam is being admitted to one end of the cylinder, the other end of the cylinder is open to the exhaust port; this operation taking place twice in each revolution.

Q. 2. How early is it possible to cut off steam on this type of engine, and what limits early cut-off?

Ans. 2. Steam cannot be cut off earlier than half stroke in this type of engine. The reason for this is that the valve has to perform the double function of admitting as well as exhausting the steam, and in order to do this properly for both strokes of the engine the eccentric must be placed at a 90 degree angle from the crank; the relative positions of eccentric and crank preventing an earlier point of cut-off than one-half stroke.

Q. 3. How may cut-off and compression be changed in a simple slide-valve engine?

Ans. 3. (a) Cut-off may be made earlier by increasing the outside lap.

(b) Cut-off may be made later by decreasing outside lap.

(c) Compression may be made greater by increasing the inside lap.

(d) Compression may be lessened by decreasing the inside lap.

Q. 4. Define clearance and explain its effect on the economy of the engine.

Ans. 4. Clearance includes all space between the piston and cylinder head when piston is at the extreme point of travel, also the space of passages for the admission of steam between admission valve and cylinder, and between cylinder and exhaust valve.

These spaces must be filled with steam every stroke, and as the steam used to fill the clearances does no appreciable amount of work it is considered as a loss. In other words, the greater the clearances the greater the loss.

Q. 5. What is the object of having a valve riding on the back of a slide-valve and in what way does it affect the valve-gear of the engine?

Ans. 5. The object of having one valve ride on the back of a slide valve is to secure a point of cut-off earlier than half stroke. This is accomplished by having each valve driven by a separate eccentric; the riding valve determining the point of cut-off while the main valve controls the admission and exhaust to and from the cylinder.

Q. 6. If a properly proportioned slide-valve is so set as to give too much lead on one end and none on the other, what effect will it have on the operations of the valve and what will remedy it?

Ans. 6. It will make the cut-off late and the compression early on the end having excessive compression, and the cut-off early and compression late on the other end.

The remedy is to shorten or lengthen the valve stem as the case may require.

Q. 7. What is understood by the term "a balanced slide-valve?"

Ans. 7. A balanced slide valve is one with surfaces so arranged that the steam in the steam chest acts to balance the valve, preventing the steam from pressing the valve on its seat, as is the case with a plain slide valve.

Q. 8. State what advantage, if any, there is in using the forced system of lubrication on engines, for both internal and external work.

Ans. 8. The advantage of forced feed of lubrication is the saving in oil; positive feed and more uniform.

Q. 11. What is the difference between a piston valve and a flat slide valve?

Ans. 11. A piston valve consists of one or more pistons, without packing, mounted upon a rod or spindle, and usually designed to correspond with annular spaces in valve chests. In construction this type of valve may be either single or multiported, it may or may not have lead or lap, and is generally considered as being balanced.

A flat or slide valve is made in one piece, and has one or more chambers on the inner face, and is commonly known as a D. or B. valve. Its design is such that it controls the admission, cut-off, compression and release of the steam, and is not balanced.

Q. 12. What are the advantages of a four-valve engine, and a plain slide valve engine?

Ans. 12. The advantages of a four-valve engine are as follows: Good distribution of steam, resulting in better economy, due to the independent action of each valve relative to opening and closing. Cylinder drainage is well-nigh perfect owing to the position of the exhaust valves being at the bottom of the cylinder, as in the Corliss type of engine. Full benefit of expansion of the steam, by admitting it at approximately boiler pressure and maintaining same up to point of cut-off, which is always automatic and proportionate to the load of the engine. This type possesses the advantage of being easily started or stopped and is easily manipulated.

The advantages of a plain slide valve consist of its low first cost, its mechanical simplicity, ease of putting it together, adaptability to portable outfits, quiet running under light loads owing to the fixed point of compression, and ease of maintenance.

Q. 13. (a) Describe a gridiron valve.
(b) Describe a poppet valve.
(c) Describe a Corliss valve.

Ans. 13. (a) A gridiron valve is a slide valve having one or more parts, arranged to correspond with the ports leading to the cylinder, and designed to give a short travel and rapid movement in opening. It is classed as a multiported valve.

(b) A poppet valve consists of one or more discs mounted on a stem or spindle, and in operation moves in a vertical plane, raising and dropping over the corresponding valve seat or seats.

(c) A Corliss valve, as the name is now applied, consists of the segmental parts of a cylindrical casting which is made to partly rotate in a circular chamber; and is called a semi-rotative valve. The construction may be either of single or multiported design, or may be arranged to admit steam through an opening in its center.

Q. 14. What range of cut-off is permissible on a four-valve engine, where all valves are operated by one eccentric?

Ans. 14. In a four-valve engine of the Corliss type, for example, where all the valves are operated by one eccentric, the range of cut-off will be from zero to about one-half stroke.

Q. 15. With a single eccentric, as mentioned in the preceding question, why cannot a long range of cut-off be obtained?

Ans. 15. Because the eccentric being set 90 degrees ahead of the crank, reaches the extreme point of its throw by the time the piston has

reached the half-stroke, therefore cut-off must occur before that time. Owing to the angularity of the connecting rod, however, it is possible to have the cut-off occur later than half-stroke, particularly on the head end of the engine. If the steam valves are set "late" it will also serve to give a late cut-off.

Q. 16. How may a four-valve engine, with two eccentrics, be adjusted to obtain a late point in cut-off?

Ans. 16. A late point of cut-off may be obtained by taking the lap off the steam valve and setting back the steam eccentric.

Q. 17. Describe a force feed method for lubricating steam engine, pump or air compressor (steam end) cylinders.

Ans. 17. A force feed lubricator consists of a mechanically operated pump to force the oil into the feed pipes leading into the steam chest and cylinders, the pump is operated by connecting to some moving part of the engine and the pump can be adjusted to feed the required amount.

Q. 18. Enumerate some of the advantages to be derived from a point of cut-off late in the stroke.

Ans. 18. It allows taking care of overloads under the control of the governor.

Q. 19. Under what conditions would it be more economical to operate a single cylinder, non-condensing engine, than a cross compound, condensing engine, assuming the load to be 500 h. p., the run each day to be nine hours?

Ans. 19. It would be more economical to run single cylinder and non-condensing engine. When you have to buy water for your condenser and where you can use the exhaust steam for heating purposes, dry kilns, etc.

Q. 20. What closes the steam valves of a detachable valve gear engine?

Ans. 20. Steam pressure on area of valve, steam vacuum dash pots, springs, and weight dash pots.

Q. 21. Give five reasons, any one of which may cause a fly ball type of steam engine governor to fail to regulate the speed of the engine.

Ans. 21. Five reasons for a fly ball governor not working would be:

1. Belt break or fly off.
2. Packing too tight on stem.
3. Pin in Governor too short.
4. Bevel gear loose on pulley shaft.
5. Dash pot out of order.

Q. 22. Why are not detachable valve gears used on high speed engines?

Ans. 22. They would not be able to engage when running faster than 100 R. P. M.

Q. 23. If you were running a four valve engine non-condensing and desired to have same run condensing, what change in the valve setting would you make?

Ans. 23. Close the exhaust valves earlier in the stroke, giving almost twice as much compression.

Q. 24. What effect would changing from non-condensing to condensing have on the engine, in relation to its developing power? What would be the effect from an economy standpoint and why?

Ans. 24. It would depend on what the cooling water cost. When water can be obtained at little cost there is from 10% to 25% saved on fuel.

Q. 25. Is the crosshead pressure greater on the guide of a vertical engine than on a horizontal engine? Give reasons.

Ans. 25. It should have read, "No, except the weight of piston rod, crosshead and connecting rod."

Q. 26. How does the length of the connecting rod as compared with that of the crank affect the pressure of the crosshead upon the guide?

Ans. 26. A short connecting rod causes a greater strain on crossheads. The usual length of connecting rod is about five or six times the length of crank.

Q. 27. How would you disconnect a crosshead from a piston rod where the connection between both was by means of a key?

Ans. 27. Remove the key. Place the engine on crank end dead center. Connect a pump with crank end of cylinder and force the rod out of the crosshead with hydraulic pressure.

CORRECTIONS.

The following is a correction in the answer to question No. 27, as it appeared in the March number of The National Engineer:

Remove the key; then by the use of a male and female gib, with taper key between them, inserted in slot with male gib next to the crosshead. A few sharp blows with a hammer will start the crosshead off the pin. Another way is to remove the crosshead pin and insert a press as follows: Take a piece of round iron as large as will go in pinhole with a hole drilled and tapered as large as possible. Make a long thread screw so it will reach from end of piston rod in crosshead out far enough to get a wrench on, and then you can press off most any crosshead made.

Q. 28. Is lead necessary in a steam engine?

Ans. 28. In a pump without a fly wheel or in a steam hammer lead is desirable and in a very slow running engine it may be useful but in the ordinary type of engines, lead is not necessary as the momentum of the rotating parts will move the piston forward until the valve can open and put steam into the cylinder.

Q. 29. Given two engines using, respectively, 15 and 30 pounds of steam per indicated horse power: All other conditions being the same, which engine will show the greater increase in economy, when using steam with 150 degrees superheat?

Ans. 29. The engine that uses the greatest weight of steam per indicated horse power will be benefited the most when using steam with 150° F superheat, because the volume of steam required is the same in any engine all other conditions being equal.

Q. 30. What pressure should there be in the receiver of a non-condensing, cross-compound engine, when the engine is running at one-half its rated speed and without load?

Ans. 30. None that could be indicated by a steam gauge.

Q. 31. What examination of an engine should an engineer make, on assuming charge of same, to assure himself that it is in condition to operate properly?

Ans. 31. An engineer on taking charge of a strange plant should make a sufficiently thorough examination to ascertain if the engine is in fair working order. Such examination should include testing the piston for leakages, examination of the cylinder for evidences of cutting or scoring, testing valves for leakages and general condition as to wear, etc., inspecting the adjustment and condition of all bearings, noting valve adjustments and connections, turning engine over by hand to ascertain clearance spaces of piston, carefully examining the oiling devices for both internal and external lubrication, and inspecting the governor to see if it is in proper working order. After thorough examination, with the engine at rest, steam should be admitted to warm cylinder, after which the engine can be started slowly and gradually brought up to speed.

Q. 32. How would you determine whether an engine connecting rod was of the correct length to give an equal clearance at each end of the engine cylinder?

Ans. 32. Disconnect the connecting rod from crosshead and place the piston at the extreme end of cylinder. While piston is in this position make a corresponding mark on the guide and crosshead for reference. Then place piston at other extreme end of cylinder, and likewise place a corresponding mark on guide and crosshead to designate point of extreme travel. Now connect up the connecting rod, and place engine on

one center. Then carefully note the difference in extreme travel of piston as compared with the marks previously made on crosshead and guide. Place engine on other center and repeat operation. In this way the clearance at each end may be readily ascertained. If the amount is greater on one end than on the other, it may be equalized by one of two methods. If the piston rod is screwed into the crosshead, and secured by jam or lock nuts, the rod may be turned around a sufficient number of times, either forward or back, to bring the piston to a position that will equalize the clearances; it being understood, of course, that there is a limit to the number of turns a rod should be moved in either direction. In turning the rod around care should be taken to see that the piston does not have to assume a new position in relation to its wearing places in the cylinder; in other words, the rod should be turned fully one complete turn and not fractional parts of same.

Where the piston rod is attached to the crosshead by means of fixed key or wedge, the equalization of clearance spaces may be brought about by using shims at the stub ends of the connecting rod.

Q. 33. (a) What is a throttling governor?
(b) What is an inertia governor?
(c) What is meant by "governor range"?

Ans. 33. (a) In a governor of the fly-ball type so constructed that when the engine attains more than a specified speed, the fly-balls are forced outward, thereby forcing a spindle attached to a valve downward. and by this action reducing the pressure of the steam admitted to the cylinder, and partially shutting off the steam until the engine resumes its normal speed, when the governor assumes a different plane, either high or low, depending upon the amount of steam needed to keep engine up to speed.

(b) An inertia governor is of the shaft or wheel type and is usually placed within or adjacent to one of the driving or balance wheels of the engine. When the shaft is turning at a constant speed, the only forces tending to make the governor weights change their position relatively are: First, centrifugal force; second, the pulling action of a spring; and third, resistances due to the connection of the governor weights with the eccentric, and these latter must be in equilibrium. As soon, however, as the speed of the governor shaft and governor wheel changes, the tendency of the governor weight or weights to continue at the same speed in consequence of inertia, comes into play, and the accelerating forces are thus developed which may aid or oppose the centrifugal action, depending on the design of the governor.

(c) Long range governors control the point of cut-off from zero to about 7/10 of the stroke, while short range governors control from zero to about ½ stroke.

Q. 34. Explain the difference between automatic cut-off, and throttling-governed engines, also the advantages of one method over the other.

Ans. 34. The difference between a throttling governor and an automatic governor is that the former reduces the steam pressure according to the load, while the volume of steam admitted to the cylinder remains constant, thus causing a wire-drawing action; whereas, with the automatic type, steam at approximately boiler pressure is admitted to the cylinder up to the point of cut-off, this point being determined by the governor according to the engine load, and the remainder of the stroke completed by expansion, making the latter method the more economical in the use of steam.

Q. 35. Regardless of design, into how many classes are steam engines divided?

Ans. 35. Condensing and non-condensing.

Q. 36. What advantage is it to have two eccentrics on a condensing engine?

Ans. 36. The use of two eccentrics permits of having the steam and exhaust valves separately actuated, and in such a manner as to permit of range of cut-off being independent of the opening and closure of exhaust valves, thus allowing the latter to be set to secure any desired amount of compression.

Q. 37. What is the difference between a surface condenser and a jet condenser?

Ans. 37. A surface condenser is so constructed that the exhaust steam does not come into direct contact with the cooling water, but is condensed by coming into contact with metal surfaces cooled by the cooling water. This is generally accomplished by discharging the exhaust steam in a receptacle having a number of small tubes through which the cooling water circulates. Their installation is generally for the two-fold purpose of saving the water of condensation and keeping the latter in good condition for return to the boilers.

With a jet condenser, the exhaust steam and the cooling water mingle, resulting in quick condensation. In many cases the injection water used renders the combination unfit for boiler feed water.

Q. 38. Why do we sometimes fail to realize the proper receiver pressure, during the first half-hour's run, of a cross-compound condensing engine?

Ans. 38. Leaks in L. P. valves which take up when all parts get hot.

Q. 39. What is a compound engine?

Ans. 39. A compound engine is one which expands steam in two or more cylinders. If expanded in three cylinders it is called a triple expansion; if in four cylinders it is called quadruple expansion.

Q. 40. Why are compound engines used?

Ans. 40. To obtain the advantage of high pressure steam, and at the same time avoid the losses due to cylinder condensation as much as possible.

If the steam be allowed to expand in two or more cylinders, the fall in temperature is divided between the cylinders, consequently the loss from condensation is considerably less.

Q. 41. What types and designs of compound engines are in general use?

Ans. 41. Horizontal, upright, tandem and cross-compound.

Q. 42. (a) Where no receiver is used in connection with a compound engine, at what angle are the engine cranks set, one with the other?

(b) Where a receiver is used, what will the relative angle of the cranks be, and why?

(c) Why are not receivers used in connection with tandem compound engines?

Ans. 42. (a) At the same angle, or at 180°. (b) Steam can be taken from the receiver at any angle of the stroke, therefore the cranks may be set at any angle, in relation to one another. (c) Because the steam exhausts from the high pressure to the working side of the low pressure piston.

Q. 43. What advantage is there in a compound engine over a single engine, where the service conditions are such that the engine must exhaust against a gauge pressure of five pounds?

Ans. 43. Not any.

Boilers.

Q. 1. Which is preferable—a diagonal or a through and through stay? Why?

Ans. 1. Through and through stays are preferable in so far as strength of the boiler is concerned, as they pull in the direction of the stress, but their use is objected to on account of the inconvenience they cause to any person entering the boiler; for this latter reason diagonal stays are very often preferred.

Q. 2. Describe what you believe to be the most correct method for conducting an inspection of a horizontal return tubular boiler.

Ans. 2. The hammer test is most correct but should be done by one of experience so that he can readily detect by the sound whether the braces have the proper tension or whether corroded or pitted or blistered or the plates are sound and should be tested inside and outside. The hydraulic test may be used in connection if desired.

Q. 3. What causes a horizontal return tubular boiler to ''pulsate'' in its setting; a kind of breathing action, as it were? And at what time is such action apt to be discernible?

Ans. 3. Pulsation of a boiler is caused by weakness and want of capacity in the boiler to supply the necessary quantity of steam, sometimes caused by a boiler being poorly designed. It is discernible most whenever forcing the fire in order to keep steam at the required point.

Q. 4. Why are not rivets made larger and spaced farther apart, in order to remove as small an amount of metal as possible.

Ans. 4. If rivets were spaced farther apart, the plate would spring between rivets when caulking, making it impossible to make the joint steam or water tight.

Q. 5. How are tubes fastened to boiler heads and made tight?

Ans. 5. Tubes are fastened to boiler heads by being rolled or expanded, and the ends beaded over to form a slight flange, enabling the tube to hold to the heads against the internal pressure in the boiler.

Q. 6. What form of tool is used in caulking seams and why? State effect of using improperly shaped tool.

Ans. 6. A flat thick chisel with rounded edges is used in caulking seams. A tool of that shape upsets the edges of the plates without cutting them. A sharp edged tool would cut the surface of the under plate, and also leave a place liable to be attacked by corrosion.

Q. 7. How are manholes reinforced?

Ans. 7. Manholes are reinforced by having a ring of castiron or steel of sufficient strength to take the stress off that part of the boiler, riveted to the plate; or by having the plate itself flanged and thus forming a strengthening rim around the manhole.

Q. 8. Why is the wide strap in a double butt strap seam placed on the inside?

Ans. 8. Triple riveted double butt strap joints have the outside rows of rivets spaced twice as far apart as the other rows, and with one strap wide enough to take in this outside row of rivets. This wide strap is placed on the inside in order that the caulking, which is done on the outside, may be done on the double sheet and on the straps having the rivets closer together, thus avoiding any springing of the plate. Placing the wide straps on the inside allows the boiler pressure to be exerted on the larger area with less liability to leakage.

Q. 9. Under average service conditions which is the most economical for boiler feeding, an exhaust injector or an ordinary duplex steam pump? In these cases it is assumed that there is ample exhaust steam to operate the injector, and that the pump delivers water to a feed water heater, which raises the temperature of the water to 190° F.

Ans. 9. An exhaust injector would be more economical to use above the Duplex feed pump, when you have no special use for the exhaust steam, of about 15%.

Q. 10. Why are rivets in double shear not twice as strong as rivets in single shear?

Ans. 10. It is probable that if the stress could be equally divided between the two shearing sections of the rivets, that rivets in double shear would be twice as strong as the same rivets in single shear, but, owing to the uncertainty of having the stress equally divided, due to imperfect alignment of holes in practical boiler work, it would not be safe to allow for rivets in double shear, more than 185 per cent of the allowable stress for the same rivets in single shear.

Q. 11. Why are some boiler and tank heads cupped out?

Ans. 11. Boiler and tank heads are sometimes cupped outward to do away with the necessity of staying. With this form of head the

strength is not wholly dependent on its stiffness, but part of the stress on the head is tensile strength, which makes this form of head much stronger than a flat head.

Q. 12. Are straight tubes or curved tubes preferable in water tube boilers?

Ans. 12. Straight tubes are preferable to curved tubes in water tube boilers, because they are easier to clean and inspect, and give a more direct passage for the circulation of water, as well as being easier to replace.

Q. 13. How are the nipples connecting tube headers and saddle piece in a B. & W. boiler fastened?

Ans. 13. The nipples connecting tube headers and saddle piece in a B. & W. boiler are expanded in the headers and saddle piece, and the ends flared or bellied out to fasten them.

Q. 14. How are the tube caps put on a B. & W. boiler?

Ans. 14. (a) Tube caps on B. & W. boilers are put on the outside and held in place by a bolt with a cap nut, the bolt passing through a yoke or yoke plate inside the tube header. The joints between the cap and header and between cap and nut are ground. Generally a little oil and graphite to make the joint tight and occasionally a thin paper gasket is used for this purpose.

(b) In the latest type of B. & W. boiler the caps are placed on the inside similar to a hand-hole plate in a return tubular boiler.

Q. 15. What results may be noted when the mud drum of a B. & W. boiler rests upon the brick work?

Ans. 15. Should the mud-drum of a B. & W. boiler rest upon the brickwork it will sustain the weight of the boiler when heated, caused by expansion of headers and nipples; these parts will then sustain the weight of the rear of the boiler, generally causing the nipples to start in headers and saddle piece, resulting in serious leaks. The mud-drum should never rest on the brickwork.

Q. 16. When is a drift pin used in boiler construction? Why is its use detrimental to good workmanship?

Ans. 16. In boiler construction a drift pin is sometimes used to force carelessly spaced rivet holes into line so that the rivet may be driven in. This distorts the rivet holes and causes strain in the metal near the holes, which makes the use of a drift pin detrimental to good workmanship.

Q. 17. Explain different methods of staying crown sheet of locomotive type of boiler.

Ans. 17. There are two methods generally followed in staying crown sheets of locomotive type of boilers. The first is by means of girder stays commonly called "fox roof stay." The ends of these girder stays rest upon the edge of side sheet of fire box; a number of stay bolts pass through crown sheet and girder stay secured at both ends with nuts and washers, thereby staying the crown sheet. The ends of girder stay are turned down, thereby causing a small water space between it and the crown sheet.

A second method is by having stay bolts pass through crown sheet and secured as in the first method; but the other end of bolt has a forked end and pin fastened to angle irons which are riveted to shell of boiler.

Q. 18. In a longitudinal lap joint, why does the outside sheet point upward, and the inside sheet downward?

Ans. 18. To prevent scale lodging on same—inside of boiler.

Q. 19. What method is used to detect a defective stay bolt as used on the side sheets of a locomotive type of boiler?

Ans. 19. Stay bolts staying flat surfaces very generally will, when giving out, fracture near the outside shell. By drilling a small hole in stay bolt, where protruding through outside shell, water and steam will rush out of hole when fracture occurs, exposing the location of the defective bolt. Stay bolts are now in the market having small holes drilled into both ends.

Q. 20. What are the usual methods for inserting stay bolts for connecting flat surfaces?

Ans. 20. Stay bolts connecting flat surfaces of a boiler are usually threaded the whole length and secured through both plates, and their ends beaded over; sometimes that portion of the stay bolt between the plates has the thread turned off smooth to prevent the lodgment of scale on the thread.

Q. 21. Explain methods of connecting inner and outer sheets of water leg of vertical tubular boiler. Which one method is the most preferable, and why?

Ans. 21. The inner and outer sheets of water leg of a vertical boiler are connected by a wrought iron ring which forms a distance piece separating the plates. Cast iron is sometimes substituted, but wrought iron is preferable. Another method is by using a wrought iron double flanged ring. This is not to be recommended, as it leaves a narrow ridge on top of ring where sediment collects. This sediment is difficult to remove.

Q. 22. Which is preferable, short or long diagonal stays? Give reasons.

Ans. 22. A long diagonal stay is preferable to a short one as the stress is more nearly in line with its length.

Q. 23. How are through and through braces usually fastened in a boiler?

Ans. 23. Through and through stays are usually fastened with a nut and washer on both inside and outside of head. The ends of rods where threaded are enlarged so that the cross sectional area at bottom of thread will be at least equal to cross sectional area of the rod.

Q. 24. When inspecting a boiler, how can one ascertain whether all through and through braces are under uniform tension?

Ans. 24. The tension on through and through stays may be judged by the sound given out when struck with a hammer. A similar tone from each indicates a uniform tension, while a dull tone indicates less tension.

Q. 25. Why is a reinforcing plate used where the blow-off pipe enters a boiler?

Ans. 25. A reinforcing plate is used where the blow-off pipe enters boiler to give greater thickness of metal to screw the blow-off pipe into. If the hole into the shell is too large to fit the pipe, the main object of the reinforcing plate is defeated, for, although the plate strengthens the shell around hole, its main object is to better secure the blow-off pipe into the shell by means of more threads.

Q. 26. Give reasons for and against the use of a submerged tube sheet in a vertical tubular boiler.

Ans. 26. The submerged tube sheet in a vertical tubular boiler has the advantage of protecting the upper end of tubes from the action of the fire. Its disadvantages are a small steam space and a tendency to prime when boiler is forced; they are then apt to carry water into the steam mains.

Q. 27. Of what material are boiler lugs made? How are lugs fastened to boiler?

Ans. 27. Boiler lugs on horizontal tubular boilers are made of cast iron and riveted to the shell.

Q. 28. How many lugs should be attached to a boiler? Give reasons.

Ans. 28. Not more than two lugs should be attached to each side of the boiler, no matter what the length of the same may be. If more were used uneven settling of brick work might throw all the weight upon the middle lug, causing a great strain upon boiler.

Q. 29. Explain the circulation of water in a B. & W. boiler.

Ans. 29. The circulation of water in a B. & W. boiler is from front to rear of steam drum, down rear tubes and headers, thence through inclined tubes to front headers, up through front headers and into steam drum.

Q. 30. Why are the mud drums of B. & W. boilers usually made of cast iron?

Ans. 30. Cast iron is used as the impurities of the water do not so readily attack cast iron as they do wrought iron or steel; and therefore, cast iron better resists corrosion. In boilers built for high pressure steel and wrought iron are sometimes used.

Q. 31. How should a fusible plug be constructed, and of what material?

Ans. 31. The body or shell is made of brass, threaded, standard pipe size, ¾″, 1″ or 1¼″. The hole through the plug is made conical to prevent the fusible metal being forced out by the pressure; the large end of the cone being always on the pressure side. The small end of the cone should not be less than ½ inch in diameter. Banca tin has been found to be the most reliable metal to use for the cone. Its melting point is about 445 degrees F.

Q. 32. Where should a fusible plug be placed in the following types of boilers?

a. Horizontal tubular.
b. Vertical tubular.
c. Locomotive.
d. Babcock & Wilcox.

Ans. 32. a. In a drop pipe from top of shell or in backhead above tubes.

b. In one of the tubes about 2 inches below the lower gauge cock, a hand hole being cut through the shell for the purpose of inserting the plug.

c. In crown sheet.

d. In a drop tube through top of shell.

Q. 33. What precautions should be observed in cutting a boiler in on the steam main which is under pressure; also when a boiler is to be cut out under the same conditions?

Ans. 33. The precautions observed should be to have steam brought up equal to pressure in main, and all pipe connections should be well drained and by pass (if any) opened to allow the pressure to equalize before opening the main valve, and should be opened very cautiously at all times, and to cut out the fire should be drawn or very low and valve then closed.

Q. 35. When a steam boiler is equipped with two pop safety valves, should the blowing point of each be the same?

Ans. 35. When two pop valves are used on one boiler one should be slightly in advance of the other.

Q. 36. What precautions should be observed when laying up a return tubular boiler for an extended period of time?

Ans. 36. Blow out boiler, while warm and clean out thoroughly and if in a dry place leave off man hole and hand hole plates. If in a damp place cover the inside of the boiler with black oil. Remove all ashes and soot in direct contact with the shell of the boiler.

Q. 37. In steam boiler practice, neglecting the efficiency of the butt-strap joint over the lap joint, name two other decided advantages of the former over the latter type of joint.

Ans. 37. The strains are more directly in the line of the metal and the plates are not injured to so great an extent in the rolling.

Q. 38. Does the normal steam pressure, or the expansion and contraction due to furnace operation, cause the greater strain in steam boilers?

Ans. 38. Expansion and contraction cause the greater strain on a steam boiler because of the enormous strain that must take place where there is unequal heating; or the heating and cooling effect of ordinary operation.

Q. 41. If a spring loaded safety valve is set at one hundred pounds, what is the method of procedure to alter the blowing point to sixty pounds?

Ans. 41. If a spring-loaded safety valve operates all right at 100 pounds' pressure it will be necessary to change the spring for a lighter one, in order to operate successfully at 60 pounds' pressure, as these springs should not be operated at a greater variation than 15 or 20 per cent.

Q. 45. Where and how should a feed water pipe enter the following types of boilers?

a. Horizontal tubular.
b. Vertical tubular.
c. Babcock & Wilcox.

Ans. 45. (a) The feed pipe may enter the boiler through top of shell near front end, or through front tube sheet just above the top row of tubes; in either case the pipe should be of brass and should extend to near the back end of boiler and deliver the water below the water line.

(b) The feed pipe should enter the boiler through the shell near the low water line, should extend across the boiler between the tubes, should be of brass, the end should be capped and the pipe perforated to distribute the water.

(c) The feed pipe should enter front of steam drum below the water line and extend some distance back into the drum.

Q. 46. Describe, in from 75 to 125 words, the special features and principles involved in the construction of the "Heine" water tube boiler.

Ans. 46. The Heine Safety Boiler has all flange steel construction, without the use of expanded joints to hold any of the parts together, with the exception of the tubes. There are no cast iron parts under tensile

stress. The water legs, constructed somewhat similar to the side sheets in a locomotive type, have a tendency, owing to their ample areas, to give more rapid circulation. The trend of the combustion gases is horizontal through the nest of tubes. The external side of tubes is cleaned by means of a steam blower inserted through the hollow stay bolts in front and rear water legs. Tube caps are on inside of water leg making joint similar to an ordinary handhole.

Q. 47. Describe, in from 75 to 125 words, the special features and principles involved in the construction of the "Cahall" water tube boilers, both vertical and horizontal type.

Ans. 47. The Cahall Vertical Water Tube Boiler consists of two drums arranged one above the other and connected with a nest of tubes. The upper, or steam drum, has an opening in the center through which gases pass to chimney. The boiler rests upon four iron brackets riveted to lower drum, supported upon four piers of the foundation. The boiler is allowed freedom of expansion without interfering with external brick work. The tubes are straight and placed in a vertical position, with a slight outward deflection from bottom to top, owing to the upper drum oeing of slightly larger diameter than the lower drum. Owing to the central hole in upper drum, there is a space in center of tubes, wide on top and gradually narrowing down towards bottom. This boiler has an external combustion chamber, and takes up very little floor space. It is extensively used in places where waste furnace heat is available, such as steel mills, etc.

The horizontal type of Cahall boilers is of the sectional header type, such as the B. & W. The Cahall boilers are fitted with swinging manhole covers. They swing on hinges, and the lifting in and out of the covers is thereby avoided.

Q. 48. Why will a fusible plug melt when covered with steam, and the same plug not melt when covered with water, all other conditions being the same?

Ans. 48. When a fusible plug is covered with water, the heat entering the plug from the fire is absorbed by the water; but when plug is covered with steam, the steam will not absorb the heat entering plug, owing to the fact that steam is only able to absorb heat less than one-third as rapidly as water.

Q. 49. What do you consider the best manner to temporarily stop the leak of a split tube in a fire tube boiler in order to avoid a shut down?

Ans. 49. A pine plug, the end of which should snugly fit the tube, and the center turned to a smaller diameter. Drive the plug into tube until the leak stops, then drive some little distance further, some two or three inches until the leak will be opposite the turned part.

Q. 50. If the crab and nut of rear hand hole plate in a horizontal tubular boiler should burn off would there be any danger of blowing water out of boiler?

Ans. 50. The burning off of a crab and nut would not allow water to blow out of boiler as long as the handhole plate itself is intact, for, as these plates are put on from the inside, the pressure holds them firmly in place.

Q. 51. How may crabs and nuts of rear hand hole plate be protected from the fire?

Ans. 51. By covering nut and crab with asbestos or fire clay.

Q. 52. Why is good circulation of water in a boiler essential to good steaming?

Ans. 52. Water is practically a nonconductor of heat. The heated water therefore does not impart the heat it receives to its surrounding particles. However, when heated it expands, thereby becoming of a lesser specific gravity than the cooler particles. This heated water will endeavor to rise while the colder portions come to be heated in turn, thus setting up currents in the water. The better the facilities in a boiler are for setting up these currents or "circulation," the more efficient will be its steaming qualities and its safety in operation.

Q. 53. Does the water level, as shown in gauge glass, always represent the true level in boiler, all connections being clear and open?

Ans. 53. If the water in the gauge glass and its connections could be kept at the same temperature as the water in boiler, it would represent the true level, but as the water in glass and connections cools off, it becomes of a greater density, and of course heavier than a corresponding amount of warmer water would be. The water contained in glass, therefore, will be able to balance a column of greater height of warmer water. When water gauge and connections are exposed in a cool place, and particularly so if the connections are long, the difference of the glass level and boiler level become more pronounced. There are known instances of the difference being some 1½ to 2 inches. That is, the water in boiler would be 1½ to 2 inches higher than that shown in glass. Immediately after thorough blowing down of glass, the true level will be shown until water begins to cool off.

Q. 54. (a) If top of gauge glass is shut off what is the result?
(b) If bottom of gauge glass is shut off what is the result?

Ans. 54. (a) By shutting off top valve of gauge glass the steam is prevented from entering glass; the steam contained in glass will almost immediately condense, allowing the water to take its place and rapidly, in fact, almost instantly filling the glass.

(b) By shutting off bottom valve of gauge glass the water is prevented from entering the glass; the steam in top of glass as it condenses will slowly fill the glass.

Q. 57. Why do pop safety valves remain open some time after boiler pressure has been reduced below the point at which they open?

Ans. 57. Owing to the beveled edges of the valves and seat, the steam after opening the valve is allowed to act upon a larger area than when valve is closed, therefore the valve will blow until the steam has fallen to a pressure too low to balance this larger area.

Q. 74. Describe in from 75 to 125 words the special features and principles involved in the construction of the Iowa boiler.

Ans. 74.—The Iowa boiler combines in its construction the return tubular and the water tube type of boiler. The upper part consists of an ordinary multi-tubular boiler. The lower part, being of the water tube type, is connected to the upper part by two water legs made in the form of an arch, the tubes connecting the legs from the sides and top of furnace and combustion chamber. Fire brick between tubes and fire clay plastering keep furnace and combustion chamber tight on sides and top. The tubes in lower part are inclined up towards rear, and circulation is through the tubes, up rear leg, through main shell and down through front leg. Impurities in the water, precipitated in the upper shell, can do no harm, as the shell is not in contact with the fire or combustion gases. The rear of combustion chamber and rear of tubes in upper shell are connected by means of a short flue for the passage of the combustion gases from lower to upper part of boiler.

Q. 75. Describe in from 75 to 125 words the special features and principles involved in the construction of a Stirling boiler.

Ans. 75. The Stirling boiler consists of three steam and water drums at the top and one water or mud drum at the bottom. Each top drum is connected to bottom drum by a bank of tubes slightly curved at the ends. The steam spaces between the upper drums and the water space between front and middle drums are also connected by means of tubes. Suitable fire brick baffle plates between the banks of tubes direct the course of the furnace gases. The feed water enters rear top drum, the coolest part of the boiler, and its temperature is gradually raised in its descent through the rear bank of tubes to mud drum below. The lower drum is protected from the furnace heat by the bridge wall, and the drum being large and the circulation therein very slight, it acts as a settling chamber for the impurities precipitated there by the feed water as it enters the drum, descending to the bottom of drum where they can be blown off through the blow-off. The drums have manholes at each end, The boiler is made of wrought material throughout.

Q. 77. What causes bagging in a boiler plate?

Ans. 77. Bagging of a boiler plate is caused by overheating, generally due to scale or other deposits accumulating to an extent that prevents the water from coming in contact with the plate. The plate then becomes soft and easily yields to the pressure acting upon it, thereby forming a bag. A plate in such condition is materially weakened and liable to be rent asunder, causing an explosion.

Q. 79. What is meant by the term, a "blistered" boiler plate, and what is the cause thereof?

Ans. 79. A blistered boiler plate is one having through imperfect material, blisters on its surface. This is caused by the laminations or layers of plate separating, the outer layer becoming burned and expanded by heat, forming a blister. Sometimes these can be cut away.

Q. 81. A boiler is fitted with a safety valve set at 100 pounds, and another safety valve also set at 100 pounds is fitted to outlet of the first one. What will be the approximate pressure in boiler when blowing off through both valves?

Ans. 81. By actual experiments it has been found that the pressures required to lift each valve from the seat, must be added to obtain the pressure in the boiler when blowing through both valves, hence, in this case, the pressure in the boiler would be approximately 200 pounds.

Q. 84. What is a dead weight safety valve? What are its advantages and disadvantages?

Ans. 84. A dead weight safety valve is a valve loaded with weights acting directly on the valve. The weights corresponding with the total pressure acting on the valve. For example, a four-inch valve intended to blow at 100 pounds per square inch would require about 1,200 pounds of weights. This type of valve has the advantage of being difficult to tamper with, as the adding of a few pounds weight would not perceptibly change the blowing point. On the other hand they are heavy and cumbersome.

Q. 85. Explain the meaning of tensile strength, shearing strength, and torsional strength.

Ans. 85. (a) Tensile strength is that strength in a substance which resists its being pulled apart lengthwise.
(b) Shearing strength is the strength in a substance which resists its being cut in two, as with a pair of shears.
(c) Torsional strength is the strength that resists twisting strains, such as shafting is subjected to.

Q. 86. Why is a punched rivet hole more injurious to a boiler than a drilled hole?

Ans. 86. Forcing a punch through boiler plates strains the metal next to the hole so punched, and starts small radial cracks, in the metal. If the hole is drilled there is no undue disturbance of the metal hence the plate has full strength right up to the edge of the hole.

Q. 87. Is there any advantage in machine riveting over hand riveting—if so, what does it consist of?

Ans. 87. Machine riveting is preferable to hand riveting because the rivet has less time to cool before the head is fully formed, also because pressure is exerted on the rivet while hot, enabling it to entirely fill the hole and making a more solid joint than can be had by hand work.

Pumps and Injectors.

Q. 1. If both are run under throttled steam, would a 8x6x10 steam pump be as economical as a 10x6x10 pump of same type; the conditions of operation are to be identical.

Ans. 1. If the work done were the same in both cases the smaller pump would be the more economical. If the work done were proportional to the pump dimensions then the larger would have the advantage.

Q. 2. Given a centrifugal pump elevating 300 gallons 25 ft. per minute, what change in power used would occur if the discharge valve be closed?

Ans. 2. There would be a large drop in power used owing to the churning or whirling of the water.

Q. 3. What device should be placed in the suction pipe to a pump which takes its supply from a place where the water holds sand and foreign matter in suspension? Describe the construction of such a device and its location.

Ans. 3. A strainer should be used on a pump suction when the pump draws its supply from rivers or ponds where foreign matter is held in suspension. A strainer consists of a casting screwed on the end of the suction pipe in the shape of a bowl. Woven wire or perforated metal is fastened to the end of the strainer bowl. The fineness of the mesh is made according to the material screened. The combined area of the openings to be three or four times the area of the pipe. Where the end of the pipe is not accessible for cleaning a strainer is placed near the pump on the suction pipe. The strainer is cast iron casting in the shape of a plug hat. The screen is fitted to the casting and placed so that the water has to flow through it. There is a cap placed on the end of casting for cleaning.

Q. 58. How would you lengthen or shorten the stroke of a duplex pump?

Ans. 58. The stroke of a duplex pump can be lengthened by increasing the lost motion. To shorten the stroke the lost motion should be decreased.

Q. 59. What is the advantage and disadvantage of an outside packed plunger pump as compared with a piston pump?

Ans. 59. An outside packed plunger pump shows at a glance if the packing is in good condition. The plungers can also be constructed to better withstand heavy pressures than ordinary piston pumps. They have the disadvantage of taking up larger floor space, and great friction of packing around plungers.

Q. 60. Should a pump, pumping hot water and receiving it at atmospheric pressure be placed above or below the source of supply? Why?

Ans. 60. The pump should be placed below its source of supply, so that the water may flow by gravity into the pump. The vapor arising from the hot water would destroy the partial vacuum necessary to raise the water, if the pump was placed above its source of supply.

Q. 61. How does a plunger or piston pump, setting above its source of supply, draw the water and deliver it out of discharge pipe?

Ans. 61. When a pump raises water it is owing to the fact that a vacuum has been created in the pump and suction pipe, the pump-piston or plunger having expelled the air out of the same. The atmospheric pressure acting upon the water supply has a tendency to destroy this vacuum by equalizing the pressures. It will, therefore, endeavor to do this by entering the suction inlet, but the end of the suction being immersed in the water, the water will be forced up into the suction pipe instead until it reaches the pump, entering same through the suction valves, being expelled through the discharge valves into the discharge pipe. Should the partial vacuum maintained by the pump in the suction pipe become equalized with the atmospheric pressure at a point below the pump, the water will only rise to this point and the pump will not be able to get water until this vacuum has been sufficiently increased.

Q. 62. What limits the height a pump can be placed above its source of supply?

Ans. 62. The atmospheric pressure limits the height a pump can be placed above its source of supply. Theoretically, this is about 34 feet, but it requires the forming of a perfect vacuum in order to obtain this result. To raise the water some 26 or 27 feet requires the pump to reduce the atmospheric pressure in the suction pipe about 12 pounds, or, in other words, the pump has to maintain a vacuum in the suction pipe of some 24 inches. Pumps doing this can be considered as giving good results.

Q. 63. Under what condition is an air-chamber on the suction pipe most beneficial in obtaining good results?

Ans. 63. Air or vacuum chambers on the suction pipe are of most benefit on pumps with a high or long lift. A vacuum chamber, owing to the compression and expansion of the air contained therein, facilitates changing a continuous into intermittent motion. The water in suction coming to a standstill upon the end of stroke is brought to rest gradually by the compression of the air in vacuum chamber, when the next stroke commences the air expands and helps the piston starting the water in motion again. Pumps running at a high rate of speed should be fitted with vacuum chambers, as it allows them to run with less noise and tends to ease the strain on the moving parts of the pump.

Q. 64. What is the object of an air-chamber on the discharge of a pump?

Ans. 64. The air chamber, due to the compression and expansion of the air contained therein, causes a steady discharge of water. During the time the piston makes a stroke the air is compressed, expanding as the piston comes to rest, acting as a cushion and gradually reducing the flow of water until the beginning of the next stroke. It also allows the valves to seat more easily.

Q. 65. What is the object of a foot valve on the suction pipe?

Ans. 65. It keeps the suction pipe full of water and greatly assists the pump in case of high lifts or leaky valves. Suction pipes exposed to freezing temperature should, if fitted with foot valves, have some means of draining water out of suction pipe when shutting down any length of time.

Q. 66. What is the best method of setting steam valves on a duplex pump?

Ans. 66. Place both pistons in center of travel; the rocker arms will then be plumb. Remove steam chest cover and set steam valves in central position over steam ports, and adjust all lost motion equally on each side of collars or nuts which move the valves. Before closing steam chest one steam valve should be moved so as to open steam port; this will facilitate starting up.

Q. 67. Why has the steam valve of a duplex pump no lap?

Ans. 67. The valves have no lap, as the pump must take steam the full stroke.

Q. 68. Why is it necessary for a steam pump to have steam admission the full length of stroke?

Ans. 68. A steam pump having no balance wheel or other means of momentum would stop if steam were cut off at partial stroke, due to the steam pressure falling after cutting off steam supply, and the resistance would soon equal and exceed the moving force.

Q. 69. What is the material best suited for the construction of pump valves handling:—

(a) Cold water.
(b) Hot water.
(c) Compressed air.

Ans. 69 (a) Pumps handling cold water should have pure rubber valves.

(b) Pumps handling hot water should be fitted with either vulcanized rubber valves or valves made of composition metal.

(c) Pumps compressing air give best results with steel valves.

Q. 70. What is the object of lost motion in the steam valve gear of a pump?

Ans. 70. The lost motion allows the valve to be motionless part of the stroke, thereby permitting the piston to make the full stroke before the valve is reversed.

Q. 71. What is the object of a cushion valve on steam end of a pump?

Ans. 71. Cushion valves are used for the purpose of regulating the degree of cushion at the end of stroke. It connects the steam and exhaust ports. Closed, it gives the greatest amount of cushion. By opening the cushion valve a little at a time, the amount of cushion required can be easily determined.

Q. 72. How is a centrifugal pump constructed?

Ans. 72. The moving part of a centrifugal pump consists of a shaft, having wings or arms radiating from the same, usually curved in a direction opposite from the direction of rotation. The whole is enclosed in a case, the case having openings in the center around the shaft and an opening at a point farthest from the shaft. The center openings are for the suction, the other opening is for the discharge.

Q. 73. How does a centrifugal pump work, and what work is it best adapted for?

Ans. 73. The shaft and arms rotating in the pump case impart motion to whatever substance is contained in the same, throwing it outward from the center by centrifugal force, expelling it out of discharge opening at the outer rim of the pump case. In this manner a vacuum is formed in the pump and suction pipe, allowing the water, or other substance pumped, to enter the pump to be in turn expelled out of discharge. These pumps must be primed when standing above their supply; this is sometimes accomplished by shutting the discharge and having a pump or ejector expel all air contained in suction pipe and pump case, starting the pump and opening discharge valve when all air is expelled. These pumps are extensively used for handling large volumes of water quickly, such as in the case in tanneries, paper mills, dry docks, etc., as they are valveless, sand, gravel and other impurities have no effect upon their operation.

Q. 74. How is a rotary pump constructed, and what are the principles governing its operation?

Ans. 74. A rotary pump is constructed of casing enclosing a piston or pistons, sometimes called impellers. They are made several ways. Some have the butments movable, while others have a movable wing on the pistons which slides in and out when passing the butments. One type is made with two gear-like impellers running together, others with impellers that are larger top and bottom, and set so that the larger part of one fits into the smaller part of the other; each impeller is mounted on separate shafts which are connected by gears.

The principle governing the action is as follows: Running at a high rate of speed the impellers create a partial vacuum, into which the atmospheric pressure forçes the water. The construction is such that the water once caught by the impellers is prevented from returning to the suction side and is forced into the discharge pipe.

Q. 76. Why is an auxiliary steam valve necessary on all single cylinder steam pumps?

Ans. 76. An auxiliary valve is necessary to operate the main valve of the pump. If the main valve of the pump was mechanically connected to piston rod of pump, the steamport would be covered slowly toward the end of stroke and the stroke would not be completed, therefore the valve would not reverse.

Q. 82. Is a belt or motor driven boiler feed pump more economical than a direct acting steam pump? If so, why?

Ans. 82. A belt or motor driven pump is more economical than a direct acting steam pump, because the power to operate it is usually taken from an engine using steam expansively.

Q. 83. About what efficiency should be obtained from an injector.

Ans. 83. The injector, taken as a pump, has a very low efficiency, much below that of the ordinary direct acting steam pump. Considered as a pump and feed water heater, it has an efficiency of nearly 100 per cent.

Q. 84. How is the steam used in an injector utilized?

Ans. 84. The steam condensed in the operation of the injector is used in heating the feed water and forcing it into the boiler. The construction of the injector is such that when steam from the boiler is admitted to it a vacuum is created in the suction pipe, causing the water to flow through the injector. The steam is condensed and its velocity imparted to the water, thus giving the water sufficient velocity to force it into the boiler.

Q. 85. Why does an injector refuse to operate when the feed water is too hot?

Ans. 85. As there is no means of exhausting the steam from an injector except by condensing it and putting it into the boiler along with the feed water, it follows that enough water must enter the injector to condense the steam; and if the water is too hot, enough of it cannot enter the injector to condense the steam, hence the injector will not work.

Q. 86. How can a feed water heater be used in conjunction with an injector?

Ans. 86. The water from an injector may be passed through a closed feed water heater before entering the boiler. An open feed water heater cannot be used in conjunction with an injector if the feed water is heated to a perceptible degree.

Q. 87. Explain fully, and in plain language, how an injector forces water into the boiler from which it receives its steam supply.

Ans. 87. To feed water into a steam boiler by means of an injector is mainly accomplished by the existing difference in velocity between the steam and the water flowing from the boiler under the same pressure. The ratio between the two velocities is quite large, leaving considerable energy for forcing fresh water into the boiler. The mass of steam which meets the comparatively cold feed water in the vacuum chamber of the injector acts upon the latter by impact of the condensed water upon the feed water. Usually the ratio between the two masses (steam and feed water) is 1 to 10 or 1 to 13 and the velocity with which the water is forced into the boiler is at least as many times less than the steam velocity as the feed water mass weighs more than the condensed steam mass, which forces the combined mass into the boiler. For illustration, the following example may be given:

Assuming the boiler pressure to be 75 pounds gauge pressure, then the velocity with which the water would flow out of the boiler would be

$$\sqrt{2\times 32.2\times 75\times 2.31}=105 \text{ feet per second.}$$

The velocity with which the steam would flow from the boiler would depend on the fall of temperature of the steam, which would be from 320 to 212° F and velocity would be (steam considered dry),

$$\sqrt{778\times 2\times 32.2\times (320-212)}=2532 \text{ feet per second.}$$

Assuming now that one pound of steam delivers 10 pounds of water into the boiler, making a total of 11 pounds, then the steam velocity is thus reduced from 2532 feet to $\frac{2532}{11}=230$ feet per second, and if 25% friction is produced in the water passage then the water will still be forced into the boiler with

$$230\times .75-105=67 \text{ feet per second.}$$

Heaters and Condensers.

Q. 37. What is the difference in construction between the open and the closed types of feed water heaters? Describe how the feed water is heated in each type?

Ans. 37. In an open feed water heater the steam and water come in actual contact with each other, the steam thereby heating the water. The feed water sometimes enters this type of heater in the form of a spray, and also quite often by filling a series of pans, overflowing them and tending to purify the water thereby. In a closed heater the feed water does not come in actual contact with the steam, but is heated by being passed through a series of tubes or a coiled tube, the steam enveloping these tubes or tube, heating the water.

Q. 38. What is a superheater?

Ans. 38. A superheater is an arrangement, usually of pipes, placed in the combustion space of the furnace, or in the uptake. The steam on its way from the boiler to the engine passes through this superheater and is superheated.

Q. 39. Describe the construction of a fuel economizer.

Ans. 39. A fuel economizer is an arrangement of tubes placed in the uptake of a boiler or battery of boilers, through which the feed water passes on its way to the boilers; the flue gases heating the feed water while passing through these tubes.

Q. 40. Describe constructional details of the most approved type of condensers, of both jet and surface type, with reasons why each type is peculiarly adaptable for some classes of service and not for others.

Ans. 40. The surface condenser consists of a number of brass tubes within a box or case. Tubes should be well tinned, and should be small as possible for good distribution of the condensing water. It should be provided with a good circulating pump to force the water rapidly around the condensing surfaces, and also be provided with an air pump to remove air and vapor. This form of a condenser is used where the water is salty or very impure as the steam does not come in direct contact with condensing water and condensed steam can be used for boiler feed water, and adapted for marine purposes.

A jet condenser consists of a box or case in which the exhaust steam comes in contact with condensing water in form of a spray falling on a scattering plate. The pump should be placed below the condenser for removing the air and water. This form of condenser takes less water and costs less to install.

Q. 41. How many square feet of cooling surface should be required in a surface condenser for an engine developing 250 I. H. P. and using 23 lbs. of steam per I. H. P. per hour?

Ans. 41. Several authorities give the constant .0944 multiplied by the pounds of steam per horse power hour as the number of square feet of cooling surface required. In this instance it will be 542 square feet.

Q. 42. How many gallons of water would be needed per hour to condense the steam from an engine running under conditions as mentioned in No. 41? Pressure of exhaust, 4 lbs. absolute. Temperature of steam at condenser is 170°, cooling water entering at 60° and leaving at 112°.

Ans. 42. 13,150 gallons. This answer is obtained by use of the following rule:

$$\frac{1128.64-170+32}{112-60}=19.05\times 250\times 23\div 8.33$$

Q. 43. About how much more cooling water is required in a surface condenser than a jet condenser?

Ans. 43. It takes about 25 to 35% more water for surface condensers than for those of the jet type. This is due to the water not coming in direct contact with the steam in the surface type of condenser.

Q. 44. In starting up a jet condensing engine, which would you start first, the engine or condenser, assuming them to work independently; and which would you shut down first? We will assume there are no pockets for water between condenser and engine.

Ans. 44. Start the condenser before starting engine, and shut down the engine before shutting down the condenser.

Q. 45. (a) What is a vacuum breaker and why are they used? (b) Is vacuum a power?

Ans. 45. (a) A vacuum breaker is a valve attached to the condensing chamber of a condenser, or to the exhaust pipe leading to the condenser. It may be arranged to be automatic in action, or not, as may be desired. It admits air to break or destroy the vacuum.

(b) Vacuum is not power, as all power in a steam engine is derived from the pressure of steam on the piston; if there is no resistance on one side of the piston the entire pressure is available on the other side of the piston.

Q. 46. The temperature of water in hot well being more than 212° and you lose your vacuum, what would be the cause?

Ans. 46. With a temperature of 212° in the hot well sufficient vapor will be present to destroy all vacuum, and under such conditions a vacuum is not possible.

Q. 47. What are the necessary cocks and valves in an engine room of a condensing engine?

Ans. 47. Throttle valve of engine, valve in exhaust pipe between engine and condenser, throttle valve for steam end of condenser pump, atmospheric valve in exhaust pipe line, valve for priming condenser, suction valve on suction pipe to condenser, and cocks on the steam pump cylinder of condenser.

Q. 48. What is the method used in cleaning the external surface of fuel economizer tubes?

Ans. 48. The fuel economizer is provided with a set of scrapers encircling the tubes which are alternately raised and lowered the entire length of the tube by mechanical means.

Q. 49. Under what circumstances is the open type of feed water heater preferable to a closed type of feed water heater?

Ans. 49. Where pumps are used instead of injector, when the feed water is full of scale forming matter, and where there are a lot of drips to be taken back into the feed water.

Furnaces, Chimneys, Draft, Fuels, Combustion, Etc.

Q. 1 What conditions must exist in the furnace of a steam boiler to insure practically complete combustion?

Ans. 1. Must have a high temperature and the proper amount of air brought into intimate contact with the fuel and distilled gases from same.

Q. 2. With coal at $2.25 per ton (of 2,000 lbs.) and an actual evaporation of 7.5 lbs.—show by a short metnod the cost of 1,000 lbs. of steam; also how many lbs. can be evaporated for one dollar?

Ans. 2. To find the cost per 1,000 lbs. of water evaporated where the cost per ton of coal and the evaporation are given: Divide the cost per ton of coal by twice the evaporation gives cost per 1,000 lbs. 6666.6 lbs. of water for $1.00, or 15 cts. per 1,000 lbs.

Q. 3. In a combined steam boiler and coal burning furnace, why, in practice, is it impossible to realize 90% efficiency?

Ans. 3. Assume a coal with 13,000 B. T. U. in it. Deduct 5% loss for ashes and 5% loss for radiation there is lost in these two ways 10%. In addition to these and some other small losses we have to heat 20 lbs. of air to each lb. of fuel and if the specific heat of the gases is .25 there is lost five heat units for each degree raise in temperature of the gases between entering and leaving the furnace. If this raise is 500 degrees we thus lose 500 times 5 or 2,500 heat units or 19% about on this account alone, making a total for these three causes almost 30%. Hence it is impossible in practice to realize 90% efficiency in a boiler furnace.

Q. 4. In a typical mechanical draft plant, what percentage of the power generated should, in good practice, be required to produce the draft?

Ans. 4. From 3% to 5%.

Q. 43. How should chimney flues and feed water mains be arranged when fuel economizers are used?

Ans. 43. Chimney flues and feed water mains should be arranged with by-pass flues and mains so that the economizer can be cut out whenever it becomes necessary to do so.

Q. 44. How does the use of an economizer affect the chimney draft; also the foreign matter contained in the feed water?

Ans. 44. Economizers reduce the temperature of the gases passing up the chimney, hence it reduces the intensity of the draft.

Heating the feed water causes foreign matter held in suspension to deposit, and as the heating takes place in the economizer the deposit will be there.

Q. 85. Describe in a general way the construction of an automatic damper regulator, and the principles governing its operation.

Ans. 85. Describing damper regulators in a general way, it may be said that two distinct types cover the field of general use. First, is the low pressure regulator, where the steam pressure acts directly on a diaphragm, which by a system of levers controls the damper or dampers. This type is extensively used for low pressure heating plants.

Then comes the high pressure type of regulator, where the steam acts on a diaphragm or piston counterbalanced by weights. This controls a valve which in turn admits water under pressure to a piston which actuates the damper. The water pressure may be taken from the boiler or other suitable source.

Q. 89. Should there be a difference in the size of a fan supplying mechanical draft to a boiler under the following conditions:

(a) Forced draft.
(b) Induced draft.

Ans. 89. Owing to the fact that air after having passed through the furnace has expanded in volume, a fan supplying cold air to the bottom of the grates can be smaller than a fan placed in the uptake of a boiler, the duty in both cases being alike in reference to work being done by the boiler.

The first would supply a forced draft, while the second would induce a draft by exhausting the air from the uptake.

As the larger fan handles air which is of a lesser density, owing to its volume being expanded, the power required to drive it would not materially differ from that necessary to operate the fan handling the cold air.

Air Compressors.

Q. 5. State what advantages there are in using an air lift for deep well service, over those to be obtained by use of deep well pumps; also conditions under which the best results may be attained by use of the latter?

Ans. 5. The advantage of an air lift over a deep well pump for deep well service, is its simplicity, being able to concentrate all the machinery in one place which can be conveniently located, and its ability to handle water containing grit without injury to the machinery, but where the wells are not scattered and water is pure the deep well pump has a greater efficiency.

Q. 8. What is the difference between the real and apparent clearance in an air compressor; how can the real clearance best be determined?

Ans. 8. The apparent clearance in an air compressor is the space left, which is not swept through by the piston and is usually very small, i. e., seldom more than ⅛ but frequently less than 1/16 of an inch between piston and cylinder head. The real clearance is the amount of space the compressed air, that is left in the compressor after completion of stroke, will occupy after it is re-expanded to the original suction pressure. This clearance can best be determined on the compressor indicator diagram and is that part of the stroke where the expansion line meets the suction pressure line, or in other words, where the prevailing pressure in the compressor during the return stroke reaches the suction pressure.

Q. 14. Given an air compressor with a cylinder 12 inches long, taking free air at atmospheric pressure (14.7 lbs.), and discharging against a pressure of 100 pounds gauge pressure; considered adiabatically, what will be pressures at 3d, 6th and 9th inches of the stroke, and at what portion of the stroke (considered in inches) will the discharge of air commence?

Ans. 14. If P_1 =absolute final air pressure,
P =absolute initial air pressure,
V_1 =final volume of air,
V =initial volume of air,

then

$$\frac{P_1}{P} = \left(\frac{V}{V_1}\right)^{1.41} \text{ and}$$

$$\frac{V}{V_1} = \left(\frac{P_1}{P}\right)^{0.71}$$

hence the pressures at the 3d, 6th and 9th inches are 20.8, 55.3 and 98 pounds absolute, respectively, and the final volume at 100 pounds gauge pressure would be 2.788 inches from the end or 76.8% of the entire stroke.

Q. 23. With a condensing, steam driven air compressor using 15 pounds of steam per horse power, and compressing 5 cubic feet of free air for each horse power exerted, how many degrees can the feed water be heated by the compressed air, if the latter gives up 300 degrees of its temperature, ignoring all losses?

Ans. 23. Assuming the temperature of the air when entering compressor to be 60° F. then 5 cu. ft. would weigh .3805 of a pound. The specific heat of air is .2375, hence the heat given off by 5 cu. ft. of air if reduced 300° F. is $.3805 \times .2375 \times 300 = 27$ B. T. U., and since 15 pounds of water must at least be fed to the boiler for every 5 cu. ft. of air compressed, it follows that the temperature the feed water can be raised amounts to only

$$\frac{27}{15} = 1.8° \text{ F.}$$

Mechanics, Piping, Refrigeration, Test Apparatus, Steam, Elevators, Gas Producers, Etc., and Miscellaneous.

Q. 1. What features should be embodied in the design of gas engines of 100 h. p. for use in driving a mixed motor and lighting load? Peak load to be of short duration at 10 per cent. overload, and normal load of about 75 h. p.

Ans. 1. The features that should be embodied in the design of gas engine should be the "Throttling Governor," very sensitive, heavy fly wheel, (3 or 4) three or four cylinder, (4) four cycle.

Q. 2. Describe the construction and operation of some one type of suction gas producer.

Ans. 2. A suction gas producer has the following parts: A generator, smoke pipe evaporator, scrubber, and gas receiver. The generator is an ordinary cylindrical stove lined with fire brick in which the coal burns. The evaporator containing water is placed inside of the steel shell of the producer or generator in contact with the fire and generates steam which is conducted through a pipe and discharged beneath the grate mixing with the air as it is drawn up into the fire. The heat of the fire decomposes this steam into its constituent parts of oxygen and hydrogen. The hydrogen increases the heating value of the fuel 20 to 25 heat units per foot. The second large vessel is what is known as the scrubber. This is a boiler iron cylinder filled with coke. The gas from the producer enters this scrubber at the bottom, passing upward to the pipe leading to the gas receiver or engine. At the top of this scrubber a water pipe enters and water is sprayed on top of the coke and runs down through the coke to the trap at the bottom. This cools the gas and washes out the dust and other impurities, which are drawn through the producer by the suction of the engine. The gas receiver is a small storage tank for gas. To start the producer a fire is kindled on the grate. The vent in the smoke pipe is opened to the outer air. The blower is started, taking from 15 to 30 minutes the first time that the producer is started. The fan must be operated until the test flame burns with a bright blue flame. Then shut the damper in the smokestack. The blower is stopped and the valve to the gas receiver is opened. The engine is then started.

Q. 3. Given the famous Ferris wheel, 250 feet in diameter: A band or tire of steel is made for same, and found to be 12 inches too long. How much larger in diameter is the band than the diameter of the wheel; and

how many degrees Fahr. drop in temperature will be needed to shrink the band so that it will fit the wheel, if the coefficient of expansion is .0000686?

Ans. 3. $$\frac{1}{(250 \times 3.1416 + 1) \times .0000686} = 185^\circ \text{ Fah.}$$

Q. 4. How wide should a double belt be to transmit 500 h. p. from a drive wheel 22 ft. in diameter running 65 r. p. m.?

Ans. 4. 78 ins. wide, $\frac{600 \times 500}{22 \times 3.1416 \times 65}$. Single belt, 7/10 of that transmitted by a double belt.

Q. 5. If the power, as given in No. 4 was to be transmitted from shaft to shaft, which would require the heavier belt; in one case the driving and receiving pulleys are both 48 inches in diameter, and in the other case the diameters are 72 inches?

Ans. 5. The belt on the 48″ pulleys would have to be 2/3 wider than the one on the 72″ pulleys as the speed in feet per minute is more.

Q. 6. What type of passenger elevator best meets the requirements of office building service, it being assumed that the lift is not over 200 ft. nor the car travel over 350 ft. per minute? Explain in detail.

Ans. 6. Electric type elevator when continued service can be had or obtained. (Reasons.) No expense when elevator not in use. Easy to operate and when properly constructed cost of maintenance very light.

Q. 7. What is the smallest size elevator installation in which it would be a paying investment to install a high duty pumping engine, one that would develop a horse power on not more than 35 pounds of steam per hour?

Ans. 7. Two (2) two-ton elevators running continuously not less than 150 lift and speed not less than 150 feet per minute.

Q. 8. Assuming a high pressure, inverted hydraulic elevator; does it use more power running light or loaded?

Ans. 8. The same amount is used under both conditions as the cylinder must be filled in either case.

Q. 9. What features of design and construction should be embodied in valves, of either the globe or gate types, for use on high pressure steam lines, where the service must be continuous?

Ans. 9. All high pressure valves should be constructed heavy enough to withstand all strains, and those of 6″ or over should have flange connections and by-pass also be constructed so valve stem could be packed when valve is open.

Q. 10. In locating standpipes for fire protection purposes, in mills or office buildings, which is preferable, the inside or outside pipes, and why?

Ans. 10. Standpipe should be placed on the outside for easy access.

Q. 11. What should the position of a globe valve be placed on pipes lying in a horizontal position?

Ans. 11. A globe valve placed in a horizontal pipe line should have its stem in a horizontal position. When so placed it prevents the trapping of water in the pipe; the valve seat will be in a vertical position, and as it is nearly the full size of the pipe it allows complete drainage. Should the stem be in a vertical position, either upward or downward, water would be trapped to a considerable extent.

Q. 12. What is a water hammer? Name some of the conditions under which they occur.

Ans. 12. A water hammer is the snapping and pounding so frequently heard in pipe systems. In its mild form it is simply annoying, but often it occurs in a violent form and becomes highly dangerous. A water hammer is produced under the following conditions: A pipe laying horizontal, imperfectly drained and containing more or less water, has live steam turned into it; this live steam striking the water will almost instantly condense and create a small area of vacuum into which the water rushes with great force, and then coming to rest, resulting in a distinct shock. The strength of the snapping or pounding depends upon the length of time it takes to condense the steam admitted to the pipe.

Q. 13. What is the best method of preventing wasting or pitting in underground steam lines, used for returning condensation?

Ans. 13. They should be of cast iron or brass and should be run in dry boxes or trenches out of contact with the earth.

Q. 14. Describe the differences between the "compression" system of refrigeration, and the one commonly termed the "absorption" system.

Ans. 14. A compression system of refrigeration is operated by means of a gas pump or compressor. The operations are compression of the gas by the compressor to about 150 lbs. Next a withdrawal of the heat caused by compression by means of cold water in contact with the pipes containing the ammonia gas. Next the expansion of the liquid and absorption by it of the heat of brine water or air to be cooled in their return to the compressor to complete another cycle. It is an alternate compression and expansion of the refrigerant.

In the absorption method in a still, aqua ammonia is used containing 26% solution of ammonia in water which is put into a vessel and a coil of steam pipe is run through the vessel. The heat of the steam heats the ammonia and water, causing the ammonia to expand and evaporate to a pressure of about 150 lbs. The gas and some condensed water pass out of the still to the dehydrating coil. The coil is enclosed in a tank which is filled with water at a temperature of about 150 degrees where the water-vapor condenses and the ammonia remains a gas. The gas and water flow to a water separator where the water goes back to the still and the gas completes the cycle as in a compression system.

Q. 15. How can transparent ice be made, by artificial means, from clear water that has not been distilled or boiled?

Ans. 15. By gentle agitation of the water to be frozen.

Q. 16. Why should an indicator card be as long as possible?

Ans. 16. So as to magnify the different lines such as admission and expansion and to separate the important points as cut off release and exhaust closure, making them all as distinct and prominent as possible. A long card more readily adapts itself to graphical measurements and proofs.

Q. 17. Define the term "superheated steam."

Ans. 17. The term, superheated steam, means steam which has a higher temperature than that normal to its pressure, or that contains more heat than it is possible to contain while in contact with water. Steam cannot be superheated when it is in direct contact with water.

Q. 18. (a). What are the advantages and disadvantages of using superheated steam?

(b). What engine valve gears are best adapted for using superheated steam?

Ans. 18. (a). The advantage of superheated steam is that, containing a greater amount of heat than that normal to its pressure, it reduces the amount of condensation in the cylinders to a minimum.

The disadvantage is the difficulty of lubricating the surfaces of valves and cylinders, as the high temperature tends to burn the lubricating material. The complex apparatus for superheating steam is somewhat of a disadvantage also.

(b). Poppet valves are best adapted for using superheated steam.

Q. 19. If steam enters an engine cylinder at 335° F. and leaves it at 225° F., what becomes of the temperature represented by the drop of 110°; no account need be taken of losses by radiation.

Ans. 19. The 110° F. did not disappear but simply became latent, i. e., they are required to keep the steam in a more expanded form or rather at a greater volume. If the steam was not released at 225° F. and no heat lost by radiation the original temperature (335° F.) would be obtained again if the piston would compress the steam back again to the original volume.

Q. 20. Describe a gravity heating system.

Ans. 20. A gravity heating system is a system where the steam, after condensation in the radiating surfaces, will, in the form of condensation be returned by gravity to the boiler, the boiler being the lowest part of the system. The returns may also return to any suitable receptacle and enter the boiler by means of a pump, in which case, the boiler may be located at any point.

Q. 21. Describe a vacuum heating system.

Ans. 21. A vacuum heating system has its returns exhausted by means of a pump or ejector, creating a vacuum in the system. When exhaust steam of low pressure is used this is very efficient, as the steam circulates thoroughly and rapidly. Steam at a pressure below the atmosphere can be used if the pump or ejector handling the returns maintains a vacuum of sufficient degree. In some cases a vacuum of 8 to 10 inches is maintained in the exhaust pipe of the engine. In order to secure this result the system must be free from all leaks, and a sufficient radiating surface must be available to condense the exhaust steam.

Q. 22. Give several simple and easily applied tests whereby the hardness of boiler feed water, or the presence of acid in same, may be detected.

Ans. 22. A few drops of a solution of good soap in alcohol if put in a vessel of water will turn it quite milky if the water is hard, and if soft will remain clear. The harder the water the less effect the soap has on it because the mineral matter neutralizes so much of it. Water which will turn blue litmus paper red before boiling the water but not after boiling contains carbonic acid.

Q. 23. In making a calorimeter test, what is the best method of securing a fair sample of the steam passing through the pipe from which sample is to be taken?

Ans. 23. A barrel calorimeter test is one of the best methods. It consists of a barrel that will hold 400 or 500 pounds of water placed on platform scales. A pipe or hose leading into it from the source of steam supply, as near the throttle as possible. A valve to admit steam when needed. The pipe or hose should be perforated and closed at end. A thermometer is also used to show the difference in the temperature of the water before and after the steam is admitted to the water.

Q. 24. What is a draft gauge, how is it constructed, and how is it used?

Ans. 24. A draft gauge is an instrument used to ascertain the amount of draft in a chimney or uptake of a boiler. This instrument is made in various forms, but all work on the same principle. In its simplest form it consists of a U-shaped graduated glass tube partially filled with water, one end of which is connected by means of a suitable piece of flexible tubing or pipe, to the chimney or uptake the draft of which is to be ascertained; the other end of the glass tube should be open to the atmosphere. The difference in the height of the water in the two legs of the tube is the measurement of the draft, and is stated in inches.

Q. 25. Describe the construction and operation of a steam pressure gauge. Why is a loop used in connecting the gauge to the boiler?

Ans. 25. Steam gauges are constructed with a tube nearly elliptical in cross section. This tube is bent nearly into a circle; as pressure is admitted inside the tube it has a tendency to straighten out, which is resisted by its own stiffness. The motion of the end of the tube is communicated to a pointer by a rack and pinion. A loop or syphon is placed in the connection between the boiler and steam gauge to trap water in the pipe so that the steam cannot enter the tube and thereby affect its stiffness.

Q. 26. Is there any difference in the construction and principle of operation between pressure and vacuum gauges?

Ans. 26. There is no difference in the construction and principle of pressure gauges and vacuum gauges. Any pressure gauge will indicate a vacuum by allowing the pointer to travel below the zero mark. However, in order to correctly read the degree of vacuum, the gauge dial would have to be properly graduated. In a vacuum gauge the pointer is, by suitable connection to the elliptical tube, made to travel from left to right, the same as the pointer in a steam gauge, and reads from 0 to 30, representing inches of vacuum. The reading from left to right is simply a matter of convenience.

Q. 27. What is a compound gauge, and where is it ordinarily used?

Ans. 27. The compound gauge has its dial graduated in such a manner that both pressure above the atmosphere, as well as pressure below the atmosphere, can be read from it. Its dial has the zero mark somewhere near the top, reading to the left, from 0 to 30, representing inches of vacuum, and to the right, reading pounds of pressure above atmosphere. Sometimes, in compound gauges, the vacuum is also indicated in pounds, reading, of course, from 0 to 15. Compound gauges are necessary where the pressure ranges below, as well as above, the atmosphere pressure. The receivers of compound engines are usually fitted with compound gauges.

Electricity.

Q. 1. Define, in a general way, the difference between direct current and alternating current.

Ans. 1. Direct current is that which flows continuously in one direction.

Alternating current is that which changes its direction of flow; this change of direction may vary from twenty-five to ten thousand times a second.

Q. 2. What is a solenoid, and for what purposes is such a device best adapted?

Ans. 2. A solenoid is an electric magnet made out of a hollow core wound with insulated wire, and although not as strong as a magnet with a solid core would be, owing to the fact that the armature of the magnet can have a long range of action and without excessive variation in the pull exerted upon it by the coil, a solenoid is preferable where long range of armature action is desired. Arc lamps and various electrical instruments are equipped with a solenoid.

Q. 3. What is meant by the term "booster set," and under what conditions is it advantageous to use such apparatus in electric lighting or power work?

Ans. 3. A "booster" set consists, usually, of a motor and generator mounted upon the same shaft, the motor using station voltage, and the generator also receiving station voltage at its negative terminals and raising, or boosting, it up to a higher voltage.

In electric lighting and electric power work, this method is often used to send current to outlying districts where the long distance transmission would cause a sufficient drop in voltage, from that at station, to give poor service.

Q. 4. What is an electric step-up transformer?

Ans. 4. Step-up transformers consist of an iron core made of thin sheets, on which are wound two sets of coils, called the primary and secondary windings; the primary windings, supplied by the lower potential, creates lines of force in the core which may be considered to continuously expand and contract, rapidly.

These lines of force are "cut" by the secondary windings and, consequently, an electromotive is induced in the secondary winding, which furnishes current to the high pressure mains.

It may be said that step-down transformers are constructed on similar lines, the only difference being in the method of winding the primary and secondary coils.

Q. 5. Why is direct current required to excite the fields of an alternating current generator?

Ans. 5. It requires current flowing continuously in the same direction to excite the fields of any magnet; if alternating current were used, the field would lose its magnetism at each alternation of the current, at the zero point. Alternating current dynamos derive the direct current necessary for their fields from a direct current dynamo, known as the exciter.

Q. 6. Describe the material used in the construction of an electro-magnet, also the method of constructing the magnet, and state what limits the magnetic force of an electro-magnet.

Ans. 6. Iron is used for commercial electro-magnets, as it remains a magnet only so long as current flows around it, whereas steel would for a long while retain the magnetic qualities after once being induced. The magnetic force is limited by the quantity of current flowing around the magnetic core and the amount of iron and its permeability contained in the core of the magnet.

Q. 7. What voltage is most economical for use on a combination lighting and motor load, and why?

Ans. 7. The most economical would be 220 volt direct current (3) three wire system on account of cheapness to install.

Q. 8. Explain the meaning of volt, ampere and ohm.

Ans. 8. (a). The volt is the unit of electromotive force, and can best be compared with the pound as used in connection with steam, water or air pressures; it represents the difference in potential which tends to force a flow of current through a conductor.

(b). The ampere is a term used for the quantity of current flowing in a circuit, and is the accepted unit of quantity.

(c). The ohm is the unit whereby the resistance in an electric circuit is measured.

The three foregoing terms bear a close relationship one with the other.

Q. 9. In what way do ohms affect amperes?

Ans. 9. The increase or diminishing of the number of ohms will directly affect the number of amperes; in other words, the current varies inversely with the resistance.

Q. 10 What is meant by the terms of (a) natural magnet and (b) an electro or induced magnet?

Ans. 10. (a). A natural magnet is a magnet that exists in a natural state, such as magnetic ore, generally called the lodestone.

(b). An electro or induced magnet is a magnet only while an electric current is passed around it by means of windings of electric wire, or if a substance lays in a field of magnetic force and thereby becomes magnetized.

Q. 11. What class of apparatus is generally found in sub-stations for the transmission of electricity, and what are the separate functions of each piece of apparatus?

Ans. 11. Sub-stations apparatus differs according to conditions, but one or more of the following will be found:

Step-down transformers to reduce voltage.

Rotary converters to change the current from A. C. to D. C. current.

Frequency changer to change to lower frequency where motor load only is used.

Boosters to raise voltage on line.

Storage batteries to relieve generator during heavy loads, also to steady the load where variation is great.

Lightning arresters. And switch-board with controlling apparatus for whatever kind installed.

Q. 12. Explain what is meant by electric lamps placed in series, and how it affects the voltage and candle-power.

Ans. 12. Lamps placed in series means that they are placed one after another on the same circuit, the current in the circuit passing through each lamp. For illustration, five 110 volt 16 candle power lamps, each using one-half ampere, are to be put on a circuit where the voltage is 550; each lamp is then in series and uses current at a potential of 110 volts, thus dividing the potential of 550 equally among the five lamps. The power used in such a case would be $5 \times .5 \times 110 = 275$ watts.

Q. 13. Given a compound D. C. generator, running in multiple, wired up in the usual way; if the circuit breaker opens and the main switch is pulled, while machine is still running, what causes the pilot lamp to explode; and what is the remedy?

Ans. 13. In the wiring up of the generator only one shunt field wire is run from switchboard to generator, this wire is connected to the machine lead next to machine under the fuse. If circuit breaker is placed on the generator and it opens, the shunt field will still be fed from the bus bar, if the main switch is pulled it opens the shunt field. The pilot light is wired from the two machine leads; when main switch is pulled the discharge or kick from the fields explodes the lamp. To remedy the trouble either change the circuit breaker to where it will not cut the field away from the armature when it opens or cut the field wire off of the machine lead and run two wires to the generator; tap one at the top of circuit breaker, or next to the generator, connect this wire to rheostat, tap the other wire to the shunt field so as to allow the armature to absorb the kick; the opening of the breaker will have no effect on the pilot-light.

Q. 14. What is meant by the term "compound wound electric generator?" What feature of construction would determine in your opinion that a generator was compound wound?

Ans. 14. It is meant that this generator has its field magnets wound with two sets of coils, one of which is connected in series, and the other one in parallel, with the armature and the external circuit.

By noting how the wiring from the field magnets and the armature wires or cables are connected up.

Q. 15. What is meant by the term "constant current generators?"

Ans. 15. A constant current generator is one which does not vary; although the voltage may vary the amount of current is constant.

Q. 16. Explain the term of neutral point in connection with electric generators.

Ans. 16. The neutral points of a generator are the positions on the commutator between which the difference in potential is greatest, and where there is the least difference in potential between adjacent bars. These points are diametrically opposite.

Q. 17. Explain the term lead in connection with electric generators.

Ans. 17. Lead is the term applied to the slight forward movement, which it is necessary to give the brushes in order to avoid sparking with the increase of load, due to the fact of a magnetic reaction of the armature due to the heavier load. Increase the lead in the direction of rotation; decrease in the opposite direction.

Q. 18. What are the conditions when an electric generator is given: (a) More lead? (b) Less lead?

Ans. 18. (a). An increase of load.
(b). A decrease of load.

Q. 19. With a generating unit consisting of a cross-compound engine of the Corliss type, and an alternator, describe method of starting same, bringing it up to speed and cutting it in on the load. This unit is supposed to operate in conjunction with others.

Ans. 19. Start up the condenser and turn on steam to the high pressure cylinder and use the bypass to the low pressure cylinder. Let the engine warm up for ten minutes or so, and while engine is warming, oil up. Then start engine, running slowly for about 15 minutes, then bring engine up to speed, throw in field switch, build up voltage and when in step with other generator throw in main switch.

Q. 20. Can a D. C. compound wound motor of large size be started under full load, without a starting box?

Ans. 20. Yes; by disconnecting the shunt and starting as a series motor after it is up to speed or nearly so put in the shunt field.

Q. 21. Explain the method of winding electric motors of the following types:
(a). Shunt wound.
(b). Series wound.
(c). Compound wound.

Ans. 21. (a). In a shunt-wound motor the current for exciting the fields is taken from the main circuit, but only in sufficient amount for excitation purposes, and forms a by-path in parallel with the main circuit.

(b) In a series-wound motor the whole of the main circuit passes through the wires conveying the current to excite the fields.

(c) In a compound-wound motor there are two circuits, one containing many turns of small wire, through which part of the main current passes, and another consisting of a lesser number of turns of large wire, through which the whole of the main circuit passes, with the exception of the amount passing through the circuit formed by the smaller wires. This type is a combination of the shunt and series types, as described in (a) and (b).

Q. 22. What effect does the strength of the fields have upon the speed of a direct current motor?

Ans. 22. Decreasing the strength of the fields increases the speed of the motor, and increasing the strength of the fields decreases the speed.

Q. 23. What is the difference between a synchronous motor, and an induction motor?

Ans. 23. A synchronous motor has its field excited from some direct current source, while its armature takes current off the alternating current line; whereas the fields of an induction motor are supplied with alternating current, and the armature is not connected to any source of current, the current being induced by the field.

The National Association of Stationary Engineers.

Organized October, 1882. Incorporated October, 1892.

Four Hundred and Fifty Subordinate Associations with Twenty Thousand Members in Forty-Eight States and Territories.

PREAMBLE.

This Association shall at no time be used for the furtherance of strikes, or for the purpose of interfering in any way between its members and their employers in regard to wages; recognizing the identity of interests between employer and employe, and not countenancing any project or enterprise that will interfere with perfect harmony between them.

Neither shall it be used for political or religious purposes. Its meetings shall be devoted to the business of the Association, and at all times preference shall be given to the education of engineers, and to securing of the enactment of engineers' license laws in order to prevent the destruction of life and property in the generation and transmission of steam as a motive power.

FORMER PRESIDENTS AND YEARS OF SERVICE.

1882-3.	H. D. Cozens	Providence, R. I.
1883-4.	James G. Beckerleg	Chicago, Ill.
1884-5.	R. J. Kilpatrick	St. Louis, Mo.
1885-6.	James G. Beckerleg	Chicago, Ill.
1886-7.	F. A. Foster	Bridgeport, Conn.
1887.	G. M. Barker	Boston, Mass.
1888.	R. O. Smith	New York City
1889.	John Fehrenbatch	Cincinnati, O.
1890.	J. J. Illingworth	Utica, N. Y.
1891.	William Powell	Cleveland, O.
1892.	C. W. Naylor	Chicago, Ill.
1893.	James D. Lynch	Philadelphia, Pa.
1894.	M. D. Nagle	New York City
1895.	Charles H. Garlick	Pittsburg, Pa.
1896.	J. W. Lane	Providence, R. I.
1897.	C. A. Collett	St. Louis, Mo.
1898.	W. T. Wheeler	New York City
1899.	Herbert E. Stone	Cambridge, Mass.
1900.	P. E. Leahy	New York City
1901.	E. G. Jacques	Detroit, Mich.
1902.	R. G. Ingleson	Cleveland, O.
1903.	P. F. Hogan,	Boston, Mass.
1904.	C. F. Wilson	Milwaukee, Wis.
1905.	R. D. Tomlinson	New York City
1906.	T. N. Kelsey	Lowell, Mass.
1907.	J. F. Carney	New York City

RULES FOR CONDUCTING BOILER TRIALS, FORMULATED BY THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. KNOWN AS THE CODE OF 1899.

I. Determine at the outset the specific object of the proposed trial, whether it be to ascertain the capacity of the boiler, its efficiency as a steam generator, its efficiency and its defects under usual working conditions, the economy of some particular kind of fuel, or the effect of changes of design, proportion, or operation; and prepare for the trial accordingly.

II. Examine the boiler, both outside and inside; ascertain the dimensions of grates, heating surfaces, and all important parts; and make a full record describing the same, and illustrating special features by sketches. The area of heating surface is to be computed from the surfaces of shells, tubes, furnaces, and fire-boxes in contact with the fire or hot gases. The outside diameter of water-tubes and the inside diameter of fire-tubes are to be used in the computation. All surfaces below the mean water level which have water on on side and products of combustion on the other are to be considered as water heating surface, and all surfaces above the mean water level which have steam on one side and products of combustion on the other are to be considered as superheating surface.

III. Notice the general condition of the boiler and its equipment, and record such facts in relation thereto as bear upon the objects in view.

If the object of the trial is to ascertain the maximum economy or capacity of the boiler as a steam generator, the boiler and all its appurtenances should be put in first class condition. Clean the heating surface inside and outside, remove clinkers from the grates and from the sides of the furnace. Remove all dust, soot, and ashes from the chambers, smoke connections and flues. Close air leaks in the masonry and poorly fitted cleaning doors. See that the damper will open wide and close tight. Test for air leaks by firing a few shovels of smoky fuel and immediately closing the damper, observing the escape of smoke through the crevices, or by passing the flame of a candle over cracks in the brickwork.

IV. Determine the character of the coal to be used. For tests of the efficiency or capacity of the boiler for comparison with other boilers, the coal should, if possible, be of some kind which is commercially regarded as a standard. For New England and that portion of the country east of the Allegheny Mountains, good anthracite egg coal, containing not over ten per cent. of the ash, and the semi-bituminous Clearfield, (Pa.), Cumberland (Md.), and Pocahontas (Va.), are thus regarded. West of the Allegheny Mountains, Pocahontas, (Va.), and New River, (W. Va.), semi-bituminous, and Youghiogheny or Pittsburg bituminous coals are recognized as standards. There is no special grade of coal mined in the Western States which is widely recognized as of superior quality or considered as a standard coal for boiler testing. Big Muddy lump, an Illinois coal mined in Jackson County, Ill., is suggested as being of sufficiently high grade to answer these requirements in districts where

it is more conveniently obtainable than the other coals mentioned above.

For tests made to determine the performance of a boiler with a particular kind of coal, such as may be specified in a contract for the sale of a boiler, the coal used should not be higher in ash and in moisture than that specified, since increase in ash and moisture above a stated amount is apt to cause a falling off of both capacity and economy in greater proportion than the proportion of such increase.

V. Establish the correctness of all apparatus used in the test for weighing and measuring. These are:

1. Scales for weighing coal, ashes, and water.
2. Tanks, or water-meters, for measuring water. Water-meters, as a rule should be used only as a check on other measurements. For accurate work, the water should be weighed or measured in a tank.
3. Thermometers and pyrometers for taking temperatures of air, steam, feed-water, waste gases, etc.
4. Pressure gauges, draught gauges, etc.

The kind and location of the various pieces of testing apparatus must be left to the judgment of the person conducting the test; always keeping in mind the main object, *that is,* to obtain authentic data.

VI. See that the boiler is thoroughly heated to its usual working temperature before the trial. If the boiler is new and of a form provided with a brick setting, it should be in regular use at least a week before the trial, so as to dry and heat the walls. If it has been laid off and become cold, it should be worked before the trial until the walls are well heated.

VII. The boiler and connections should be proved to be free from leaks before beginning a test, and all water connections, including below and extra feed pipes, should be disconnected, stopped with blank flanges, or bled through special openings beyond the valves, except the particular pipe through which water is fed to the boiler during the trial. During the test the blow-off and feed pipes should remain exposed to view.

If an injector is used, it should receive steam directly through a felted pipe from the boiler being tested.*

If the water is metered after it passes the injector, its temperature should be taken at the point where it leaves the injector. If the quantity is determined before it goes to the injector the temperature should be determined on the suction side of the injector, and if no change of temperature occurs other than that due to the injector, the temperature thus determined is properly that of the feed water. When the temperature changes between the injector and the boiler, as by the use of a heater or by radiation, the temperature at which the water enters and leaves the injector and that at which it enters the boiler should all be taken. In that case the weight to be used is that of the water leaving the injector, computed from the heat units if not directly measured, and the temperature, that of the water entering the boiler.

Let w=weight of water entering the injector.
x=weight of steam entering the injector.
h_1=heat units per pound of water entering the injector.
h_2=heat units per pound of steam entering the injector.
h_3=heat units per pound of water leaving injector.
Then $w+x$=weight of water leaving injector.

* In feeding a boiler undergoing test with an injector taking steam from another boiler, or from the main steam pipe from several boilers, the evaporative results may be modified by a difference in the quality of the steam from such source compared with that supplied by the boiler being tested, and in some cases the connection to the injector may act as a drip for the main steam pipe. If it is known that the steam from the main pipe is of the same pressure and quality as that furnished by the boiler undergoing the test, the steam may be taken from such main pipe.

$$x = w \frac{h_3 - h_1}{h_2 - h_3}$$

See that the steam main is so arranged that water of condensation cannot run back into the boiler.

VIII. Duration of the test—For tests made to ascertain either the maximum economy or the maximum capacity of a boiler, irrespective of the particular class of service for which it is regularly used, the duration should be at least ten hours of continuous running. If the rate of combustion exceeds 25 pounds of coal per square foot of grate surface per hour, it may be stopped when a total of 250 pounds of coal has been burned per square foot of grate.

In cases where the service requires continuous running for the whole 24 hours of the day, with shifts of firemen a number of times during that period, it is well to continue the test for at least 24 hours.

When it is desired to ascertain the performance under the working conditions of practical running, whether the boiler be regularly in use 24 hours a day or only a certain number of hours out of each 24, the fires being banked the balance of the time, the duration should not be less than 24 hours.

IX. Starting and stopping a test—The conditions of the boiler and furnace in all respects should be, as nearly as possible, the same at the end as at the beginning of the test. The steam pressure should be the same; the water level the same; the fire upon the grates should be the same in quantity and condition; and the walls, flues, etc., should be of the same temperature. Two methods of obtaining the desired equality of conditions of the fire may be used, viz.; those which were called in the Code of 1885 "the standard method" and "the alternate method," the latter being employed where it is inconvenient to make use of the standard method.†

X. Standard method of starting and stopping a test—Steam being raised to the working pressure, remove rapidly all the fire from the grate, close the damper, clean the ash-pit, and as quickly as possible start a new fire with weighed wood and coal, noting the time and the water level* while the water is in a quiescent state, just before lighting the fire.

At the end of the test remove the whole fire, which has been burned low, clean the grates and ash-pit, and note the water level when the water is in a quiescent state, and record the time of hauling the fire. The water level should be as nearly as possible the same as at the beginning of the test. If it is not the same, a correction should be made by computation, and not by operating the pump after the test is completed.

XI. Alternate method of starting and stopping a test.—The boiler being thoroughly heated by a preliminary run, the fires are to be burned low and well cleaned. Note the amount of coal left on the grate as nearly as it can be estimated; note the pressure of steam and the water level. Note the time and record it as the starting time. Fresh coal which has been weighed should now be fired. The ash-pits should be thoroughly cleaned at once after starting. Before the end of the test the fires should be burned low, just as before the start, and the fires cleaned in

† The Committee concludes that it is best to retain the designations "standard" and "alternate," since they have become widely known and established in the minds of engineers and in the reprints of the Code of 1885. Many engineers prefer the "alternate" to the "standard" method on account of its being less liable to error due to cooling of the boiler at the beginning and end of a test.

* The gauge-glass should not be blown out within an hour before the water level is taken at the beginning and end of test, otherwise an error in the reading of the water level may be caused by a change in the temperature and density of the water in the pipe leading from the bottom of the glass into the boiler.

such a manner as to leave a bed of coal on the grates of the same depth, and in the same condition, as at the start. When this stage is reached, note the time and record it as the stopping time. The water level and steam pressures should previously be brought as nearly as possible to the same point as at the start. If the water level is not the same as at the start, a correction should be made by computation, and not by operating the pump after the test is completed.

XII. Uniformity of conditions—In all trials made to ascertain maximum economy or capacity, the conditions should be maintained uniformly constant. Arrangements should be made to dispose of the steam so that the rate of evaporation may be kept the same from beginning to end. This may be accomplished in a single boiler by carrying the steam through a waste-steam pipe, the discharge from which can be regulated as desired. In a battery of boilers, in which only one is tested, the draft may be regulated on the remaining boilers, leaving the test boiler to work under a constant rate of production.

Uniformity of conditions should prevail as to the pressure of steam, the height of water, the rate of evaporation, the thickness of fire, the times of firing and the quantity of coal fired at one time, and as to the intervals between the times of cleaning the fires.

The method of firing to be carried on in such tests should be dictated by the expert or person in responsible charge of the test, and the method adopted should be adhered to by the fireman throughout the test.

XIII. Keeping the records—Take note of every event connected with the progress of the trial, however unimportant it may appear. Record the time of every occurrence and the time of taking every weight and every observation.

The coal should be weighed and delivered to the fireman in equal proportions, each sufficient for not more than one hour's run, and a fresh portion should not be delivered until the previous one has all been fired. The time required to consume each portion should be noted, the time being recorded at the instant of firing the last of each portion. It is desirable that at the same time the amount of water fed into the boiler should be accurately noted and recorded, including the height of the water in the boiler and the average pressure of steam and temperature of feed during the time. By thus recording the amount of water evaporated by successive portions of coal, the test may be divided into several periods if desired, and the degree of uniformity of combustion, evaporation, and economy analyzed for each period. In addition to these records of the coal and the feed water, half hourly observations should be made of the temperature of the feed water, of the flue-gases, of the external air in the boiler room, of the temperature of the furnace when a furnace pyrometer is used, also of the pressure of steam, and of the readings of the instruments for determining the moisture of the steam. A log should be kept on properly prepared blanks containing columns for record of the various observations.

When the "standard method" of starting and stopping the test is used, the hourly rate of combustion and evaporation and the horsepower should be computed from the records taken during the time when the fires are in active condition. This time is somewhat less than the actual time which elapses between the beginning and end of the run. The loss of time due to kindling the fire at the beginning and burning it out at the end makes this course necessary.

XIV. Quality of steam—The percentage of moisture in steam should be determined by the use of either a throttling or a separating steam calorimeter. The sampling nozzle should be placed in the vertical steam pipe rising from the boiler. It should be made of ½-inch pipe, and should extend across the diameter of the steam pipe to within half an inch of the opposite side, being closed at the end and perforated with not less

than twenty ½-inch holes equally distributed along and around its cylindrical surface, but none of these holes should be nearer than ½-inch to the inner side of the steam pipe. The calorimeter and the pipe leading to it should be well covered with felting. Whenever the indications of the throttling or separating calorimeter show that the percentage of moisture is irregular, or occasionally in excess of three per cent., the results should be checked by a steam separator placed in the steam pipe as close to the boiler as convenient, with a calorimeter in the steam pipe just beyond the outlet from the separator. The drip from the separator should be caught and weighed, and the percentage of moisture computed therefrom added to that shown by the calorimeter.

Superheating should be determined by means of a thermometer placed in a mercury-well inserted in the steam pipe. The degree of superheating should be taken as the difference between the reading of the thermometer for superheated steam and the readings of the same thermometer of saturated steam at the same pressure as determined by a special experiment, and not by reference to steam tables.

XV. Sampling the coal and determining its moisture—As each barrow load or fresh portion of coal is taken from the coal pile, a representative shovelful is selected from it and placed in a barrel or box in a cool place and kept until the end of the trial. The samples are then mixed and broken into pieces not exceeding one inch in diameter, and reduced by the processes of repeated quartering and crushing until a final sample weighing about five pounds is obtained, and the size of the larger pieces is such that they will pass through a sieve with ¼-inch meshes. From this sample two one-quart, air-tight glass preserving jars, or other air-tight vessels which will prevent the escape of moisture from the sample, are to be promptly filled, and these samples are to be kept for subsequent determinations of moisture and of heating value and for chemical analyses. During the process of quartering, when the sample has been reduced to about 100 pounds, a quarter to a half of it may be taken for an approximate determination of moisture. This may be made by placing it in a shallow iron pan, not over three inches deep, carefully weighing it and setting the pan in the hottest place that can be found on the brickwork of the boiler setting or flues keeping it there for at least 12 hours, and then weighing it. The determination of moisture thus made is believed to be approximately accurate for anthracite and semi-bituminous coals, and also for Pittsburg or Youghiogheny coal; but it cannot be relied upon for coals mined west of Pittsburg, or for other coals containing inherent moisture. For these latter coals it is important that a more accurate method be adopted. The method recommended by the Committee for all accurate tests, whatever the character of the coal, is described as follows:

Take one of the samples contained in the glass jars, and subject it to a thorough air drying, by spreading it in a thin layer and exposing it for several hours to the atmosphere of a warm room, weighing it before and after, thereby determining the quantity of the surface moisture it contains. Then crush the whole of it by running through an ordinary coffee mill adjusted so as to produce somewhat coarse grains (less than 1-16 inch), thoroughly mix the crushed sample, select from it a portion of from 10 to 50 grams, weigh it in a balance which will easily show a variation as small as 1 part in 1,000, and dry it in an air or sand bath at a temperature between 240 and 280 degrees Fahr. for one hour. Weigh it and record the loss, then heat and weigh it again repeatedly, at intervals of an hour or less, until the minimum weight has been reached and the weight begins to increase by oxidation of a portion of the coal. The difference between the original and the minimum weight is taken as the moisture in the air-dried coal. This moisture test should preferably be made on duplicate samples, and the results should agree within 0.3 to 0.4 of one per cent., the mean of the two determinations being taken as the

correct result. The sum of the percentage of moisture thus found and the percentage of surface moisture previously determined is the total moisture.

XVI. TREATMENT OF ASHES AND REFUSE—The ashes and refuse are to be weighed in a dry state. If it is found desirable to show the principal characteristics of the ash, a sample should be subjected to a proximate analysis and the actual amount of incombustible material determined. For elaborate trials a complete analysis of the ash and refuse should be made.

XVII. CALORIC TESTS AND ANALYSIS OF COAL.—The quantity of the fuel should be determined either by heat test or by analysis, or by both.

The rational method of determining the total heat of combustion is to burn the sample of coal in an atmosphere of oxygen gas, the coal to be sampled as directed in Article XV of this code.

The chemical analysis of the coal should be made only by an expert chemist. The total heat of combustion computed from the results of the ultimate analysis may be obtained by the use of Dulong's formula, pages 106 and 131.

It is desirable that a proximate analysis should be made, thereby determining the relative proportions of volatile matter and fixed carbon. These proportions furnish an indication of the leading characteristics of the fuel, and serve to fix the class to which it belongs. As an additional indication of the characteristics of the fuel, the specific gravity should be determined.

XVIII. ANALYSIS OF FLUE GASES—The analysis of the flue gases is an especially valuable method of determining the relative value of different methods of firing, or of different kinds of furnaces. In making these analyses great care should be taken to procure average samples—since the composition is apt to vary at different points of the flue. The composition is also apt to vary from minute to minute, and for this reason the drawings of gas should last a considerable period of time. Where complete determinations are desired, the analyses should be intrusted to an expert chemist. For approximate determinations the Orsat or the Hempel apparatus may be used by the engineer.

For a continuous indication of the amount of carbonic acid (CO_2) present in the flue-gases, an instrument may be employed which shows the weight of the sample of gas passing through it.

XIX. SMOKE OBSERVATIONS—It is desirable to have a uniform system of determining and recording the quantity of smoke produced where bituminous coal is used. The system commonly employed is to express the degree of smokiness by means of percentages dependent upon the judgment of the observer. The Committee does not place much value upon a percentage method, because it depends so largely upon the personal element, but if this method is used, it is desirable, that so far as possible, a definition be given in explicit terms as to the basis and method employed in arriving at the percentage. The actual measurement of a sample of soot and smoke by some form of meter is to be preferred.

XX. MISCELLANEOUS—In tests for purposes of scientific research, in which the determination of all the valuables entering into the test is desired, certain observations should be made which are in general unnecessary for ordinary tests. These are the measurements of the air supply, the determination of its contained moisture, the determination of the amount of heat lost by radiation, of the amount of infiltration of air through the setting, and (by condensation of all the steam made by the boiler) of the total heat imparted to the water.

As these determinations are rarely undertaken, it is not deemed advisable to give directions for making them.

XXI. Calculations of efficiency—Two methods of defining and calculating the efficiency of a boiler are recommended. They are:

1. Efficiency of the boiler

$$= \frac{\text{Heat absorbed per lb. combustible}}{\text{Caloric value of 1 lb. combustible.}}$$

2. Efficiency of the boiler and grate

$$= \frac{\text{Heat absorbed per lb. coal}}{\text{Caloric value of 1 lb. coal.}}$$

The first of these is sometimes called the efficiency based on combustible, and the second efficiency based on coal. The first is recommended as a standard of comparison for all tests, and this is the one which is understood to be referred to when the word "efficiency" alone is used without qualification. The second, however, should be included in a report of a test, together with the first, whenever the object of the test is to determine the efficiency of the boiler and the furnace together with the grate (or mechanical stoker), or to compare different furnaces, grates, fuels or methods of firing.

The heat absorbed per pound of combustible (or per pound of coal) is to be calculated by multiplying the equivalent evaporation from and at 212 degrees per pound combustible (or coal) by 965.7.

XXII. The heat balance—An approximate "heat balance," or statement of the distribution of the heating value of the coal among the several items of heat utilized and heat lost may be included in the report of a test when analyses of the fuel and of the chimney-gases have been made. The methods of computing the heat balance and the form in which it should be reported, are given in chapter on Steam Boiler Efficiency.

XXIII. Report of the trial—The data and results should be reported in the manner given in either one of the two following tables, omitting lines where the tests have not been made as elaborately as provided for in such tables. Additional lines may be added for data relating to the specific object of the test. The extra lines should be classified under the headings provided in the tables, and numbered as per preceding line, with sub-letters *a*, *b*, etc. The Short Form of Reports is recommended for commercial tests and as a convenient form of abridging the longer form of publication when saving space is desirable. For elaborate trials, it is recommended that the full log of the trial be shown graphically, by means of a chart.

DATA AND RESULTS OF EVAPORATIVE TEST.

Made by .... of .... boiler at .... to determine ....
Principal conditions governing the trial..............................
....
Kind of fuel...
Kind of furnace..
State of the weather ....
Method of starting and stopping the test ("standard" or "alternate," Art. X and XI, Code)..
1. *Date of trial*...
2. Duration of trial..hours.

Dimensions and Proportions.

(A complete description of the boiler, and drawings of the same if of unusual type, should be given on an annexed sheet.)

3. *Grate surface*........*width*........*length*........*area*........sq. ft.
4. Height of furnace..ins
5. Approximate width of air spaces in grate........................in.

6. Proportion of air space to whole grate surface..............per cent.
7. *Water-heating surface*..sq. ft.
8. *Superheating surface*...sq. ft.
9. Ratio of water-heating surface to grate surface.................—to 1.
10. Ratio of minimum draft area to grate surface..............1 to ——.

Average Pressures.

11. *Steam pressure by gauge*.............................lbs. per sq. in.
12. *Draft between damper and boiler*......................ins. of water
13. Force of draft in furnace..............................ins. of water
14. Force of draft or blast in ash-pit......................ins. of water

Average Temperatures.

15. Of external air...deg.
16. Of fireroom ....deg.
17. Of steam ....deg.
18. Of feed water entering heater.................................deg.
19. Of feed water entering economizer.............................deg.
20. *Of feed water entering boiler*...............................deg.
21. *Of escaping gases from boiler*...............................deg.
22. Of escaping gases from economizer.............................deg.

Fuel.

23. Size and condition..
24. Weight of wood used in lighting fire..........................lbs.
25. Weight of coal as fired.......................................lbs.
26. *Percentage of moisture in coal*..........................per cent.
27. *Total weight of dry coal consumed*...........................lbs.
28. *Total ash and refuse*..
29. Quality of ash and refuse.......................................
30. Total combustible consumed....................................lbs.
31. *Percentage of ash and refuse in dry coal*................per cent.

Proximate Analysis of Coal.

		Coal.	Combustible.
32.	Fixed carbon	per cent.	per cent.
33.	Volatile matter	"	"
34.	Moisture	"	——
35.	Ash	"	——
		100 %	100 %
36.	Sulphur, separately determined................	"	"

Ultimate Analysis of Dry Coal.

(Art. XVII., Code.)

		Coal.	Combustible.
37.	Carbon (C)	per cent	per cent.
38.	Hydrogen (H)	"	"
39.	Oxygen (O)	"	"
40.	Nitrogen (N)	"	"
41.	Sulphur (S)	"	"
42.	Ash	"	"
		100 %	100 %
43.	Moisture in sample of coal as received.........	— "	— "

Analysis of Ash and Refuse.

44. Carbon .... per cent.
45. Earthy matter .... per cent.

Fuel per Hour.

46. *Dry coal consumed per hour* .... lbs.
47. Combustible consumed per hour .... lbs.
48. *Dry coal per sq. ft. of grate surface per hour* .... lbs.
49. Combustible per square foot of water heating surface per hour ..... lbs.

Calorific Value of Fuel.

(Art. XVII., Code.)

50. *Calorific value by oxygen calorimeter, per lb. of dry coal* ...... B. T. U.
51. *Calorific value by oxygen calorimeter, per lb. of combustible* ... B. T. U.
52. Calorific value by analysis, per lb. of dry coal .... B. T. U.
53. Calorific value by analysis, per lb. of combustible .... B. T. U.

Quality of Steam.

54. *Percentage of moisture in steam* .... per cent.
55. Number of degrees of superheating .... deg.
56. Quality of steam (dry steam=unity) ....

Water.

57. *Total weight of water fed to boiler* .... lbs.
58. Equivalent water fed to boiler from and at 212 degrees .... lbs.
59. *Water actually evaporated, corrected for quality of steam* .... lbs.
60. Factor of evaporation .... lbs.
61. Equivalent water evaporated into dry steam from and at 212 degrees. (Item 59×Item 60.) .... lbs.

Water per Hour.

62. *Water evaporated per hour, corrected for quality of steam* .... lbs.
63. *Equivalent evaporation per hour from and at 212 degrees* .... lbs.
64. *Equivalent evaporation per hour from and at 212 degrees per square foot of water heating surface* .... lbs.

Horse-Power.

65. *Horse-Power developed* ($34\frac{1}{2}$ *lbs. of water evaporated per hour into dry steam from and at 212 degrees, equals one horse-power*) H. P.
66. *Builders' rated horse-power* .... H. P.
67. *Percentage of builders' rated horse-power developed* .... per cent.

Economic Results.

68. *Water apparently evaporated under actual conditions per pound of coal as fired.* (*Item* 57÷*Item* 25.) .... lbs.
69. *Equivalent evaporation from and at 212 degrees per pound of coal as fired.* (*Item* 61÷*Item* 25) .... lbs.
70. *Equivalent evaporation from and at 212 degrees per pound of dry coal.* (*Item* 61÷*Item* 27.) .... lbs.
71. *Equivalent evaporation from and at 212 degrees per pound of combustible.* (*Item* 61÷*Item* 30.) .... lbs.

(If the equivalent evaporation, Items 69, 70 and 71, is not corrected for the quality of steam, the fact should be stated.)

Efficiency.

(Art. XXI., Code.)

72. *Efficiency of boiler; heat absorbed by the boiler per lb. of combustible divided by the heat value of one lb. of combustible*..per cent.
73. *Efficiency of boiler, including the grate; heat absorbed by the boiler, per lb. of dry coal, divided by the heat value of one lb. of dry coal*..per cent.

Cost of Evaporation.

74. *Cost of coal per ton of*........*lbs. delivered in boiler room*......\$....
75. Cost of fuel for evaporating 1,000 lbs. of water under observed conditions ....\$....
76. *Cost of fuel used for evaporating* 1,000 *lbs. water from and at* 212 *degrees* ....\$....

Smoke Observations.

77. Percentage of smoke as observed.........................per cent.
78. Weight of soot per hour obtained from smoke meter...........ounces.
79. Volume of soot per hour obtained from smoke meter..........cub. in.

Methods of Firing.

80. Kind of firing (spreading, alternate or coking).................
81. Average thickness of fire.......................................
82. Average intervals between firing for each furnace during time when fires are in normal condition..........................
83. Average interval between times of leveling or breaking up.......

Analysis of the Dry Gases.

84. Carbon dioxide (CO_2)..................................per cent.
85. Oxygen (O) .... "
86. Carbon monoxide (CO).................................. "
87. Hydrogen and hydrocarbons............................. "
88. Nitrogen (by difference) (N)........................... "

100 per cent.

FACTORS OF EVAPORATION.

Temp. F. of Feed Water.	STEAM PRESSURES, POUNDS BY GAUGE.																								
	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	260	270	280	290	300
32	1.214	1.216	1.220	1.222	1.225	1.227	1.229	1.231	1.232	1.234	1.236	1.237	1.239	1.240	1.241	1.243	1.244	1.245	1.246	1.247	1.248	1.250	1.251	1.252	1.253	1.254
40	1.206	1.209	1.212	1.214	1.216	1.219	1.220	1.222	1.224	1.226	1.227	1.229	1.230	1.232	1.233	1.234	1.236	1.237	1.238	1.239	1.240	1.241	1.242	1.243	1.244	1.245
50	1.195	1.197	1.201	1.204	1.206	1.208	1.210	1.212	1.214	1.215	1.217	1.218	1.220	1.221	1.223	1.224	1.225	1.226	1.228	1.229	1.230	1.231	1.232	1.233	1.234	1.235
60	1.185	1.188	1.191	1.193	1.196	1.198	1.200	1.202	1.203	1.205	1.207	1.208	1.210	1.211	1.212	1.214	1.215	1.216	1.217	1.218	1.219	1.220	1.221	1.222	1.223	1.224
70	1.175	1.178	1.180	1.183	1.185	1.187	1.189	1.191	1.193	1.194	1.196	1.197	1.199	1.200	1.202	1.203	1.205	1.206	1.207	1.208	1.209	1.210	1.211	1.212	1.213	1.214
80	1.164	1.167	1.170	1.173	1.175	1.177	1.179	1.181	1.183	1.184	1.186	1.187	1.189	1.190	1.192	1.193	1.194	1.195	1.196	1.198	1.199	1.200	1.201	1.202	1.203	1.204
90	1.154	1.157	1.160	1.162	1.165	1.167	1.169	1.170	1.172	1.174	1.175	1.177	1.179	1.180	1.181	1.183	1.184	1.185	1.186	1.187	1.188	1.189	1.190	1.191	1.192	1.193
100	1.144	1.147	1.150	1.152	1.154	1.156	1.158	1.160	1.162	1.164	1.165	1.167	1.168	1.170	1.171	1.172	1.174	1.175	1.176	1.177	1.178	1.179	1.180	1.181	1.182	1.183
110	1.133	1.136	1.139	1.142	1.144	1.146	1.148	1.150	1.152	1.153	1.155	1.156	1.158	1.159	1.160	1.162	1.163	1.164	1.166	1.167	1.168	1.169	1.170	1.171	1.172	1.173
120	1.123	1.126	1.129	1.131	1.133	1.136	1.138	1.140	1.141	1.143	1.145	1.146	1.147	1.149	1.150	1.151	1.153	1.154	1.155	1.156	1.157	1.158	1.159	1.160	1.161	1.162
130	1.113	1.116	1.118	1.121	1.123	1.125	1.127	1.129	1.130	1.132	1.134	1.136	1.137	1.138	1.140	1.141	1.142	1.144	1.145	1.146	1.147	1.148	1.149	1.150	1.151	1.152
140	1.102	1.105	1.108	1.110	1.113	1.115	1.117	1.119	1.120	1.122	1.124	1.125	1.127	1.128	1.129	1.131	1.132	1.133	1.134	1.135	1.136	1.137	1.138	1.139	1.140	1.141
150	1.091	1.095	1.098	1.100	1.102	1.104	1.106	1.108	1.110	1.111	1.113	1.115	1.116	1.118	1.119	1.120	1.121	1.123	1.124	1.125	1.126	1.127	1.128	1.129	1.130	1.131
160	1.081	1.084	1.087	1.090	1.092	1.094	1.096	1.098	1.100	1.101	1.103	1.104	1.106	1.107	1.108	1.110	1.111	1.112	1.113	1.115	1.116	1.117	1.118	1.119	1.120	1.121
170	1.070	1.074	1.077	1.079	1.081	1.083	1.0 5	1.087	1.089	1.091	1.092	1.094	1.095	1.097	1.098	1.099	1.101	1.102	1.103	1.104	1.105	1.106	1.107	1.108	1.109	1.110
180	1.060	1.063	1.066	1.069	1.071	1.073	1.075	1.077	1.079	1.080	1.082	1.083	1.085	1.086	1.088	1.089	1.090	1.091	1.093	1.094	1.095	1.096	1.097	1.098	1.099	1.100
190	1.050	1.053	1.056	1.058	1.060	1.063	1.065	1.066	1.068	1.070	1.071	1.073	1.074	1.076	1.077	1.078	1.080	1.081	1.082	1.083	1.084	1.085	1.086	1.087	1.088	1.089
200	1.039	1.043	1.045	1.048	1.050	1.052	1.054	1.056	1.058	1.059	1.061	1.063	1.064	1.065	1.067	1.068	1.069	1.071	1.072	1.073	1.074	1.075	1.076	1.077	1.078	1.079
210	1.029	1.032	1.035	1.037	1.040	1.042	1.044	1.046	1.047	1.049	1.051	1.052	1.053	1.055	1.056	1.057	1.059	1.060	1.061	1.062	1.063	1.064	1.065	1.066	1.067	1.068
220	1.019	1.022	1.024	1.027	1.029	1.031	1.033	1.035	1.037	1.039	1.040	1.042	1.043	1.045	1.046	1.047	1.048	1.050	1.051	1.052	1.053	1.054	1.055	1.056	1.057	1.058
230	1.008	1.011	1.014	1.017	1.019	1.021	1.023	1.025	1.027	1.028	1.030	1.031	1.033	1.034	1.035	1.037	1.038	1.039	1.040	1.041	1.043	1.044	1.045	1.046	1.047	1.047
240	1.9977	1.001	1.004	1.006	1.008	1.011	1.013	1.014	1.016	1.018	1.019	1.021	1.022	1.024	1.025	1.026	1.028	1.029	1.030	1.031	1.032	1.033	1.034	1.035	1.036	1.037
250	0.9873	0.9904	0.9909	0.9956	0.9979	1.000	1.002	1.004	1.006	1.007	1.009	1.010	1.012	1.013	1.015	1.016	1.017	1.018	1.020	1.021	1.022	1.023	1.024	1.025	1.026	1.027
260	0.9768	0.9799	0.9826	0.9851	0.9874	0.9896	0.9915	0.9934	0.9952	0.9968	0.9985	0.9999	1.001	1.003	1.004	1.005	1.007	1.008	1.009	1.010	1.011	1.012	1.013	1.014	1.015	1.016
270	0.9663	0.9695	0.9722	0.9747	0.9769	0.9791	0.9811	0.9829	0.9848	0.9863	0.9881	0.9895	0.9910	0.9924	0.9937	0.9949	0.9962	0.9974	0.9986	0.9997	1.001	1.002	1.003	1.004	1.005	1.006
280	0.9560	0.9591	0.9618	0.9643	0.9666	0.9688	0.9707	0.9725	0.9743	0.9759	0.9777	0.9791	0.9806	0.9820	0.9833	0.9845	0.9858	0.9870	0.9882	0.9893	0.9904	0.9914	0.9924	0.9934	0.9944	0.9953
290	0.9455	0.9486	0.9514	0.9539	0.9561	0.9583	0.9603	0.9621	0.9639	0.9655	0.9673	0.9687	0.9702	0.9715	0.9729	0.9741	0.9754	0.9766	0.9777	0.9789	0.9799	0.9809	0.9820	0.9830	0.9840	0.9849
300	......	0.9382	0.9409	0.9434	0.9457	0.9485	0.9498	0.9517	0.9534	0.9551	0.9568	0.9582	0.9597	0.9610	0.9624	0.9636	0.9649	0.9661	0.9672	0.9684	0.9694	0.9704	0.9715	0.9725	0.9735	0.9744

The values for intermediate pressures and feed water temperatures may, with sufficient accuracy for all practical purposes, be obtained by interpolation. If *exact* values are necessary they may be computed by the Formula

$$\text{Factor of Evaporation} = \frac{H - t + 32}{965.8}$$

In which H = total heat of steam above 32°, and t = the temperature Fahrenheit of the boiler feed water.

REQUIRED HOURLY EVAPORATION PER BOILER HORSE-POWER AT VARIOUS FEED TEMPERATURES AND STEAM PRESSURES.

Feed Temperature Fahr.	STEAM PRESSURE IN POUNDS BY GAUGE.																				
	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200
50	29.51	29.29	29.14	29.02	28.92	28.84	28.77	28.70	28.64	28.59	28.54	28.49	28.45	28.41	28.37	28.33	28.29	28.26	28.23	28.20	28.17
60	29.77	29.55	29.40	29.28	29.18	29.09	29.02	28.95	28.89	28.84	28.79	28.74	28.69	28.65	28.61	28.57	28.54	28.51	28.48	28.45	28.42
70	30.04	29.81	29.66	29.54	29.44	29.35	29.27	29.21	29.15	29.09	29.04	28.99	28.94	28.90	28.86	28.82	28.78	28.75	28.72	28.69	28.66
80	30.31	30.08	29.93	29.80	29.70	29.61	29.53	29.46	29.40	29.34	29.29	29.24	29.19	29.15	29.11	29.07	29.03	29.00	28.97	28.94	28.91
90	30.59	30.36	30.20	30.07	29.97	29.88	29.80	29.73	29.67	29.61	29.55	29.50	29.45	29.41	29.37	29.33	29.29	29.25	29.22	29.19	29.16
100	30.88	30.64	30.47	30.34	30.24	30.15	30.07	30.00	29.93	29.87	29.82	29.77	29.72	29.67	29.63	29.59	29.55	29.51	29.48	29.45	29.42
110	31.17	30.93	30.76	30.63	30.52	30.43	30.34	30.27	30.20	30.14	30.09	30.04	29.99	29.94	29.90	29.86	29.82	29.78	29.74	29.71	29.68
120	31.46	31.22	31.05	30.91	30.80	30.71	30.63	30.55	30.48	30.42	30.36	30.31	30.26	30.21	30.17	30.13	30.09	30.05	30.01	29.98	29.95
130	31.76	31.52	31.34	31.20	31.09	30.99	30.91	30.83	30.76	30.70	30.65	30.59	30.54	30.49	30.45	30.41	30.37	30.33	30.29	30.25	30.22
140	32.07	31.82	31.64	31.50	31.38	31.29	31.20	31.12	31.05	30.99	30.93	30.88	30.83	30.78	30.73	30.69	30.65	30.61	30.57	30.53	30.50
150	32.39	32.12	31.94	31.80	31.68	31.58	31.50	31.42	31.35	31.28	31.22	31.17	31.12	31.07	31.02	30.97	30.93	30.89	30.85	30.81	30.78
160	32.71	32.44	32.26	32.11	31.99	31.89	31.80	31.72	31.65	31.58	31.52	31.46	31.41	31.36	31.31	31.27	31.23	31.19	31.15	31.11	31.08
170	33.03	32.76	32.58	32.43	32.31	32.20	32.11	32.03	31.96	31.89	31.83	31.77	31.71	31.66	31.61	31.56	31.52	31.48	31.44	31.40	31.37
180	33.37	33.09	32.90	32.75	32.63	32.52	32.43	32.34	32.27	32.20	32.14	32.08	32.02	31.97	31.92	31.87	31.83	31.79	31.75	31.71	31.67
190	33.71	33.43	33.23	33.08	32.95	32.84	32.75	32.66	32.59	32.52	32.45	32.39	32.33	32.28	32.23	32.18	32.14	32.10	32.06	32.02	31.98
200	34.06	33.77	33.57	33.41	33.28	33.17	33.08	32.99	32.91	32.84	32.77	32.71	32.65	32.60	32.55	32.50	32.45	32.41	32.37	32.33	32.29
212	34.49	34.18	33.98	33.80	33.69	33.58	33.48	33.39	33.31	33.24	33.17	33.11	33.05	32.99	32.94	32.89	32.84	32.80	32.76	32.72	32.68

STEAM CONSUMPTION, POUNDS PER INDICATED HORSE POWER *

TYPE OF ENGINE.	Steady Loads.		Variable Loads. 50 to 125 per cent.		Extreme Variations, Railway Work, etc., 0 to 150 per cent.	
	Non-Condensing.	Condensing	Non-Condensing	Condensing	Non. Condensing.	Condensing.
High Speed, simple	32	28	34	30	36	31
High Speed, compound	23	18	25	21	27	22.5
Slow Speed, simple	25	21	28	23	31.5	26.5
Slew Speed, compound	20	15	22.5	18	26	23
High Speed, triple exp	17.5	13	20	16	....	....
Slow Speed, triple exp	14.5	12.5	17	15	....	....

APPROXIMATE HEATING VALUE OF GENERAL GRADES OF COAL PER POUND OF COMBUSTIBLE B. T. U.

KIND OF COAL.	PER CENT. OF COMBUSTIBLE.		HEATING VALUE PER POUND OF COMBUSTIBLE.
	FIXED CARBON.	VOLATILE MATTER.	
Anthracite	97.0 to 92.5	3.0 to 7.5	14,600 to 14,800
Semi-anthracite	92.5 to 87.5	7.5 to 12.5	14,700 to 15,500
Semi-bituminous	87.5 to 75.	12.5 to 25.	15,500 to 16,000
Bituminous, Eastern	75. to 60.	25. to 40.	14,800 to 15,200
Bituminous, Western	65. to 50.	35. to 50.	13,500 to 14,800
Lignite	Under 50.	Over 50.	11,000 to 13,500

STEAM DISCHARGES.

Absolute Initial Pressure per Square Inch. Pounds.	Velocity of Outflow at Constant Density, Feet per Second.*	Actual Velocity of Outflow, Expanded. Feet per Second.	Discharge per Square Inch of Orifice per Minute. Pounds.	Horse-Power per Square Inch of Orifice if H. P. = 30 lbs. per hour.
25.37	863	1,401	22.81	45.6
30.	867	1,408	26.84	53.7
40.	874	1,419	35.18	70.4
50.	880	1,429	44.06	88.1
60.	885	1,437	52.59	105.2
70.	889	1,444	61.07	122.1
75.	891	1,447	65.30	130.6
90.	895	1,454	77.94	155.9
100.	898	1,459	86.34	172.7
115.	902	1,466	98.76	197.5
135.	906	1,472	115.61	231.2
155.	910	1,478	132.21	264.4
165.	912	1,481	140.46	280.9
215.	919	1,493	181.58	363.2

COMPARISON OF OIL AND COAL.

B. T. U. Per Pound of Coal.	Pounds of Coal Equal to One Barrel of Oil.	Barrels of Oil Equal to One Short Ton of Coal.
10,000	620	3.23
11,000	564	3.55
12,000	517	3.87
13,000	477	4.19
14,000	443	4.52
15,000	413	4.84

DIMENSIONS OF CHIMNEYS BY KENT'S FORMULA.

Diameter in Inches.	Area in Square Feet.	HEIGHT OF CHIMNEY IN FEET.																									Equivalent Square Chimney. Side of Square. Inches.	Diameter in Inches.
		80	85	90	95	100	105	110	115	120	125	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200		
		COMMERCIAL HORSE POWER.																										
30	4.91	107	110	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	27	30
33	5.94	133	137	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	30	33
36	7.07	163	168	178	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	32	36
39	8.30	196	202	208	214	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	35	39
42	9.62	231	238	248	251	258	295	271	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	38	42
48	12.57	311	320	330	339	348	356	365	373	381	389	396	....	....	....	....	....	....	....	....	....	....	....	....	....	....	43	48
54	15.90	....	415	427	438	449	461	472	482	493	503	513	523	532	542	....	....	....	....	....	....	....	....	....	....	....	48	54
60	19.64	....	....	536	551	565	579	593	606	619	632	644	657	669	680	692	704	715	....	....	....	....	....	....	....	....	54	60
66	23.76	....	....	....	676	694	711	728	744	760	776	791	806	821	835	849	864	877	891	904	918	....	....	....	....	....	59	66
72	28.27	....	....	....	....	835	856	876	896	913	934	952	970	988	1006	1023	1040	1056	1073	1089	1105	1120	1136	1151	....	....	64	72
78	33.18	....	....	....	....	....	1014	1038	1062	1084	1107	1129	1150	1171	1192	1212	1232	1252	1272	1291	1310	1328	1346	1364	1382	1400	70	78
84	38.48	....	....	....	....	....	....	1214	1241	1268	1294	1320	1345	1370	1394	1418	1441	1464	1487	1509	1531	1553	1574	1595	1616	1637	75	84
90	44.18	....	....	....	....	....	....	....	1435	1466	1496	1526	1555	1584	1612	1639	1666	1693	1719	1745	1771	1795	1820	1845	1869	1893	80	90
96	50.27	....	....	....	....	....	....	....	1643	1678	1718	1747	1780	1818	1845	1876	1907	1938	1968	1998	2027	2056	2084	2112	2140	2167	86	96
102	56.75	....	....	....	....	....	....	....	....	1905	1944	1983	2021	2058	2094	2130	2165	2200	2234	2268	2301	2333	2366	2397	2429	2459	91	102
108	63.62	....	....	....	....	....	....	....	....	....	2190	2234	2276	2318	2359	2399	2439	2478	2516	2554	2592	2628	2664	2700	2736	2771	96	108
114	70.88	....	....	....	....	....	....	....	....	....	....	2499	2547	2594	2640	2685	2729	2773	2816	2858	2900	2941	2982	3022	3061	3100	101	114
120	78.54	....	....	....	....	....	....	....	....	....	....	....	2833	2885	2936	2986	3036	3084	3132	3179	3226	3271	3316	3361	3405	3448	107	120
132	95.03	....	....	....	....	....	....	....	....	....	....	....	3450	3514	3576	3637	3697	3756	3815	3872	3929	3984	4039	4093	4147	4200	117	132
144	113.10	....	....	....	....	....	....	....	....	....	....	....	....	4205	4279	4352	4424	4495	4565	4632	4701	4768	4834	4899	4963	5026	128	144

STANDARD DIMENSIONS OF WROUGHT IRON AND STEEL STEAM, GAS AND WATER PIPE.

Diameter.			Nominal Thickness.	Circumference.		Transverse Areas.			Length of Pipe per Square Foot of		Length of Pipe Containing one Cubic Foot.	Nominal Weight per Foot.	Number of Threads per Inch of Screw.
Nominal Internal	Actual External Diameter.	Approximate Internal Diameter.		External.	Internal.	External.	Internal.	Metal.	External Surface.	Internal Surface.			
Inch.	Inches.	Inches.	Inches.	Inches.	Inches,	Sq. Inch.	Sq. Inch	Sq. Inch.	Feet.	Feet.	Feet.	Pounds.	
1/8	.405	.27	.068	1.272	.848	.129	.0573	.0717	9.44	14.15	2513.	.241	27
1/4	.54	.364	.088	1.696	1.144	.229	.1041	.1249	7.075	10.49	1383.3	.42	18
3/8	.675	.494	.091	2.121	1.552	.358	.1917	.1663	5.657	7.73	751.2	.559	18
1/2	.84	.623	.109	2.639	1.957	.554	.3048	.2492	4.547	6.13	472.4	.837	14
3/4	1.05	.824	.113	3.299	2.589	.866	.5333	.3327	3.637	4.635	270.	1.115	14
1	1.315	1.048	.134	4.131	3.292	1.358	.8626	.4954	2.904	3.645	166.9	1.668	11½
1¼	1.66	1.38	.14	5.215	4.335	2.164	1.496	.668	2.301	2.768	96.25	2.244	11½
1½	1.9	1.611	.145	5.969	5.061	2.835	2.038	.797	2.01	2.371	70.66	2.678	11½
2	2.375	2.067	.154	6.461	6.494	4.43	3.356	1.074	1.608	1.848	42.91	3.609	11½
2½	2.875	2.468	.204	9.032	7.753	6.492	4.784	1.708	1.328	1.547	30.1	5.739	8
3	3.5	3.067	.217	10.996	9.636	9.621	7.388	2.243	1.091	1.245	19.5	7.536	8
3½	4.	3.548	.226	12.566	11.146	12.566	9.887	2.679	.955	1.077	14.57	9.001	8
4	4.5	4.026	.237	14.137	12.648	15.904	12.73	3.174	.849	.949	11.31	10.665	8
4½	5.	4.508	.246	15.708	14.162	19.635	15.961	3.674	.764	.848	9.02	12.49	8
5	5.563	5.045	.259	17.477	15.849	24.306	19.99	4.316	.687	.757	7.2	14.502	8
6	6.625	6.065	.28	20.813	19.054	34.472	28.888	5.584	.577	.63	4.98	18.762	8
7	7.625	7.023	.301	23.955	22.063	45.664	38.738	6.926	.501	.544	3.72	23.271	8
8	8.625	7.982	.322	27.096	25.076	58.426	50.04	8.386	.443	.478	2.88	28.177	8
9	9.625	8.937	.344	30.238	28.076	72.76	62.73	10.03	.397	.427	2.29	33.701	8
10	10.75	10.019	.366	33.772	31.477	90.763	78.839	11.924	.355	.382	1.82	40.065	8
11	11.75	11.	....	36.914	34.558	108.434	95.033	13.401	.325	.347	1.51	45.028	8
12	12.75	12.	....	40.055	37.7	127.677	113.098	14.579	.299	.319	1.27	48.985	8

EXPERIMENTS ON STEAM PIPE COVERING.

Kind of Covering.	Diam. of Test Pipe. Inches.	Thickness of Covering. Inches.	Temperatures Fah.		B. T. U. per Hour per Square Foot of Pipe Surface.		Date of Test.	Testing Expert.
			Steam.	Air.	Total.	Per Degree Difference.		
Hair Felt....................	2	0.96	302.8	71.4	89.6	0.387	1901	Jacobus
" "	8	0.82	348.3	69.0	117.9	0.422	1894	Brill
Remanit for intermediate pressure	2	0.88	304.5	73.3	100.3	0.434	1901	Jacobus
Remanit for high pressure...	2	1.30	306.6	76.1	83.7	0.363	1901	Jacobus
Mineral Wood......	8	1.30	344.1	58.3	81.3	0.284	1894	Brill
Champion Mineral Wool.....	8	1.44	346.1	74.3	86.1	0.317	1894	Brill
Rock Wool	8	1.60	344.1	63.0	72.0	0.256	1894	Brill
Asbestos Sponge Felted......	2	1.125	364.8	60.7	145.0	0.477	1901	Barrus
" " "	10	1.375	364.8	62.8	85.0	0.248	1901	Barrus
" " "	2	1.14	309.2	79.4	59.7	0.260	1901	Jacobus
Magnesia	4	1.12	388.0	72.0	147.0	0.465	1896	Norton
"	2	1.09	354.7	80.1	155.8	0.567	1896	Paulding
"	8	1.25	344.1	66.3	106.6	0.384	1895	Brill
"	2	1.08	310.9	81.6	69.8	0.304	1901	Jacobus
"	2	1.00	365.2	64.6	155.0	0.515	1901	Barrus
"	10	1.19	365.2	66.0	103.0	0.347	1901	Barrus
Asbestos, Navy Brand	2	1.20	309.2	79.4	69.9	0.304	1901	Jacobus
" " "	2	1.125	365.2	64.6	176.0	0.585	1901	Barrus
" " "	10	1.375	365.2	66.8	112.0	0.375	1901	Barrus
Manville Sectional	8	1.70	345.5	78.3	93.4	0.394	1894	Brill
" "	2	1.31	354.7	80.1	157.0	0.572	1896	Paulding
" "	4	1.25	388.0	72.0	143.0	0.453	1896	Norton
Asbestos Air Cell............	4	1.12	388.0	72.0	166.0	0.525	1896	Norton
" " "...........	2	.96	303.3	72.3	165.5	0.716	1901	Jacobus
Asbestos Fire Felt...........	8	1.30	344.7	79.0	133.5	0.502	1894	Brill
" " "	2	1.00	354.7	80.1	198.0	0.721	1896	Paulding
" " "	2	.99	307.4	72.5	180.0	0.766	1901	Jacobus
Fossil Meal	8	.75	347.1	75.3	238.0	0.876	1894	Brill
Riley Cement	8	.75	347 9	74.3	260.0	0.950	1894	Brill

TABLE OF PROPERTIES OF SATURATED STEAM.

Total Pressure per Sq Inch.	Temperature in Fahrenh't Degrees.	Total Heat in Heat Units from Water at 32° Fahr.	Latent Heat in Heat Units	Density or Weight of One Cubic Foot	Volume of One Pound of Steam.	Relative Volume, or Cub. Ft. from One of Water.	Factor of Equivalent Evaporation, at 212°.
1	102	1113.05	1042.964	.0030	330.36	20620	0.965
2	126.266	1120.45	1026.010	.0058	172.08	10720	0.972
3	141.622	1125.131	1015.254	.0085	117.52	7326	0.977
4	153.070	1128.625	1007.229	.0112	89.62	5600	0.981
5	162.330	1131.449	1000.727	.0137	72.66	4535	0.984
6	170.123	1133.826	995.219	.0163	61.21	3814	0.986
7	176.910	1135.896	990.471	.0189	52.94	3300	0.988
8	182.910	1137.726	986.245	.0214	46.69	2910	0.990
9	188.316	1139.375	982.434	.0239	41.79	2607	0.992
10	193.240	1140.877	978.958	.0264	37.84	2360	0.994
15	213.025	1146.912	964.973	.0387	25.85	1612	1.000
20	227.917	1151.454	954.415	.0511	19.72	1220.3	1.005
25	240.000	1155.139	945.825	.0634	15.99	984.8	1.008
30	250.245	1158.263	938.925	.0755	13.46	826.8	1.012
35	259.176	1160.987	932.152	.0875	11.65	713.4	1.015
40	267.120	1163.410	926.472	.0994	10.27	628.2	1.017
45	274.296	1165.600	921.334	.1111	9.18	561.8	1.019
50	280.854	1167.600	916.631	.1227	8.31	508.5	1.021
55	286.897	1169.442	912.290	.1343	7.61	464.7	1.023
60	292.520	1171.158	908.247	.1457	7.01	428.5	1.025
65	297.777	1172.762	904.462	.1569	6.49	397.7	1.027
70	302.718	1174.269	900.899	.1681	6.07	371.2	1.028
75	307.388	1175.692	897.526	.1792	5.68	348.3	1.030
80	311.812	1177.042	894.330	.1901	5.35	328.3	1.031
85	316.021	1178.326	891.286	.2010	5.05	310.5	1.033
90	320.039	1179.551	888.375	.2118	4.79	294.7	1.034
95	323.884	1180.724	885.588	.2234	4.55	280.6	1.035
100	327.571	1181.849	883.914	.2330	4.33	267.9	1.036
105	331.113	1182.929	880.342	.2434	4.14	265.5	1.037
110	334.523	1183.970	877.865	.2537	3.97	246.0	1.038
115	337.814	1184.974	875.472	.2640	3.80	236.3	1.039
120	340.995	1185.944	873.155	.2742	3.65	227.6	1.040
125	344.074	1186.883	870.911	.2842	3.51	219.7	1.041
130	347.059	1187.794	868.735	.2942	3.38	212.3	1.042
140	352.757	1189.535	864.566	.3138	3.16	199.0	1.044
150	358.161	1191.180	860.621	.3340	2.96	187.5	1.046
160	363.277	1192.741	856.874	.3520	2.79	177.3	1.047
170	368.158	1194.228	853.294	.3709	2.63	168.4	1.049
180	372.822	1195.650	849.869	.3889	2.49	160.4	1.051
190	377.291	1197.013	846.584	.4072	2.37	153.4	1.052
200	381.573	1198.310	843.432	.4249	2.26	147.1	1.053
250	401.072	1203.735	831.222	.5464	1.83	114	1.059
300	418.225	1208.737	819.610	.6486	1.54	96	1.064
350	431.956	1212.580	810.690	.7498	1.33	83	1.068
400	444.919	1217.094	800.198	.8502	1.18	73	1.073

PROPERTIES OF SATURATED STEAM.

Pressure above Vacuum. Lbs. per Sq. Inch.	Temperature Degrees Fahrenheit.	Heat of Liquid above 32° Fahrenheit. B. T. U.	Latent Heat above 32° Fahrenheit B. T. U.	Total Heat above 32° Fahrenheit. B. T. U.	Density, or Weight per Cubic Foot. Pounds.
2	126.3	94.4	1026.1	1120.5	0.00576
4	153.1	121.4	1007.2	1128.6	0.01107
6	170.1	138.6	995.2	1133.8	0.01622
8	182.9	151.5	986.2	1137.7	0.02125
10	193.3	161.9	979.0	1140.9	0.02621
12	202.0	170.7	972.9	1143.6	0.03111
14	209.6	178.3	967.5	1145.8	0.03600
14.7	212.0	180.8	965.8	1146.6	0.03760
16	216.3	185.1	962.8	1147.9	0.04067
18	222.4	191.3	958.5	1149.8	0.04547
20	228.0	196.9	954.6	1151.5	0.05023
22	233.1	202.0	951.0	1153.0	0.05495
24	237.8	206.8	947.6	1154.4	0.05966
26	242.2	211.2	944.6	1155.8	0.06432
28	246.4	215.4	941.7	1157.1	0.06899
30	250.3	219.4	938.9	1158.3	0.07360
32	254.0	223.1	936.3	1159.4	0.07821
34	257.5	226.7	933.7	1160.4	0.08280
36	260.9	230.0	931.5	1161.5	0.08736
38	264.1	233.3	929.2	1162.5	0.09191
40	267.1	236.4	927.0	1163.4	0.09644
42	270.1	239.3	925.0	1164.3	0.1009
44	272.9	242.2	923.0	1165.2	0.1054
46	275.7	245.0	921.0	1166.0	0.1099
48	278.3	247.6	919.2	1166.8	0.1144
50	280.9	250.2	917.4	1167.6	0.1188
52	283.3	252.7	915.7	1168.4	0.1233
54	285.7	255.1	914.0	1169.1	0.1277
56	288.1	257.5	912.3	1169.8	0.1321
58	290.3	259.7	910.8	1170.5	0.1366
60	292.5	261.9	909.3	1171.2	0.1409
62	294.7	264.1	907.7	1171.8	0.1453
64	296.7	266.2	906.2	1172.4	0.1497
66	298.8	268.3	904.7	1173.0	0.1541
68	300.8	270.3	903.3	1173.6	0.1584
70	302.7	272.2	902.1	1174.3	0.1628
72	304.6	274.1	900.8	1174.9	0.1671
74	306.5	276.0	899.4	1175.4	0.1714
76	308.3	277.8	898.2	1176.0	0.1757
78	310.1	279.6	896.9	1176.5	0.1801
80	311.8	281.4	895.6	1177.0	0.1843
82	313.5	283.2	894.4	1177.6	0.1886
84	315.2	285.0	893.1	1178.1	0.1930
86	316.8	286.7	891.9	1178.6	0.1973
88	318.5	288.4	890.7	1179.1	0.2016
90	320.0	290.0	889.6	1179.6	0.2058
92	321.6	291.6	888.4	1180.0	0.2101
94	323.1	293.2	887.3	1180.5	0.2144
96	324.6	294.8	886.2	1181.0	0.2186
98	326.1	296.4	885.0	1181.4	0.2229
100	327.6	297.9	884.0	1181.9	0.2271
102	329.0	299.4	882.9	1182.3	0.2314
104	330.4	300.9	881.8	1182.7	0.2356

PROPERTIES OF SATURATED STEAM—(Continued).

Pressure above Vacuum Lbs. per Sq. Inch.	Temperature, Degrees Fahrenheit.	Heat of Liquid above 32° Fahrenheit. B. T. U.	Latent Heat above 32° Fahrenheit B. T. U.	Total Heat above 32° Fahrenheit. B. T. U.	Density, or Weight per Cubic Foot. Pounds.
106	331.8	302.3	880.8	1183.1	0.2399
108	333.2	303.8	879.8	1183.6	0.2441
110	334.6	305.2	878.8	1184.0	0.2484
112	335.9	306.6	877.8	1184.4	0.2526
114	337.2	308.0	876.8	1184.8	0.2568
116	338.5	309.4	875.8	1185.2	0.2610
118	339.8	310.7	874.9	1185.6	0.2653
120	341.1	312.0	874.0	1186.0	0.2695
122	342.3	313.3	873.0	1186.3	0.2736
124	343.5	314.6	872.1	1186.7	0.2779
126	344.7	315.9	871.2	1187.1	0.2820
128	345.9	317.1	870.3	1187.4	0.2862
130	347.1	318.4	869.4	1187.8	0.2904
132	348.3	319.6	868.6	1188.2	0.2946
134	349.5	320.8	867.7	1188.5	0.2988
136	350.6	322.0	866.9	1188.9	0.3030
138	351.7	223.2	866.0	1189.2	0.3072
140	352.9	324.4	865.1	1189.5	0.3113
142	354.0	325.6	864.3	1189.9	0.3155
144	355.1	326.7	863.5	1190.2	0.3197
146	356.1	327.8	862.8	1190.6	0.3239
148	357.2	328.9	862.0	1190.9	0.3280
150	358.3	330.0	861.2	1191.2	0.3321
152	359.3	331.1	860.4	1191.5	0.3363
154	360.3	332.2	859.6	1191.8	0.3405
156	361.4	333.3	858.9	1192.2	0.3447
158	362.4	334.3	858.2	1102.5	0.3488
160	363.4	335.4	857.4	1192.8	0.3530
162	364.4	336.4	856.7	1193.1	0.3572
164	365.4	337.5	855.9	1193.4	0.3614
166	366.4	338.5	855.2	1143.7	0.3655
168	367.3	339.5	854.5	1194.0	0.3695
170	368.3	340.5	853.8	1194.3	0.3737
172	369.2	341.5	853.1	1194.6	0.3778
174	370.2	342.5	852.3	1194.8	0.3820
176	371.1	343.5	851.6	1195.1	0.3862
178	372.1	344.4	851.0	1195.4	0.3904
180	373.0	345.4	850.3	1195.7	0.3945
182	373.9	346.4	849.6	1196.0	0.3987
184	374.8	347.3	848.9	1196.2	0.4029
186	375.7	348.2	848.3	1196.5	0.4070
188	376.6	349.2	847.6	1196.8	0.4111
190	377.4	350.1	847.0	1197.1	0.4153
192	378.3	351.0	846.3	1197.3	0.4194
194	379.2	351.9	845.7	1197.6	0.4236
196	380.0	352.8	845.0	1197.8	0.4278
198	380.9	353.7	844.4	1198.1	0.4318
200	381.7	354.6	843.8	1198.4	0.4359
202	382.6	355.4	843.2	1198.6	0.4399
204	383.4	356.3	842.6	1198.9	0.4441
206	384.2	357.2	841.9	1199.1	0.4482
208	385.1	358.0	841.4	1199.4	0.4524
210	385.9	358.9	840.7	1199.6	0.4565

PROPERTIES OF SATURATED STEAM—(Continued).

Pressure above Vacuum Lbs. per Sq. Inch.	Temperature, Degrees Fahrenheit.	Heat of Liquid above 32° Fahrenheit. B. T. U.	Latent Heat above 32° Fahrenheit. B. T. U.	Total Heat above 32° Fahrenheit. B. T. U.	Density, or Weight per Cubic Foot. Pounds.
212	386.7	359.7	840.2	1199.9	0.4607
214	387.5	360.6	839.5	1200.1	0.4648
216	388.3	361.4	839.0	1200.4	0.4690
218	389.1	362.2	838.4	1200.6	0.4731
220	389.8	363.0	837.8	1200.8	0.4772
222	390.6	363.9	837.2	1201.1	0.4813
224	391.4	364.7	836.6	1201.3	0.4855
226	392.2	365.5	836.1	1201.6	0.4896
228	392.9	366.3	835.5	1201.8	0.4939
230	393.7	367.1	834.9	1202.0	0.4979
232	394.5	367.9	834.3	1202.2	0.5021
234	395.2	368.6	833.9	1202.5	0.5062
236	395.9	369.4	833.3	1202.7	0.5103
238	396.7	370.2	832.7	1202.9	0.5144
240	397.4	371.0	832.2	1203.2	0.5186
242	398.1	371.7	831.7	1203.4	0.5226
244	398.9	372.5	831.1	1203.6	0.5268
246	399.6	373.2	830.6	1203.8	0.5311
248	400.3	374.0	830.0	1204.0	0.5353
250	401.0	374.7	829.5	1204.2	0.5393
252	401.7	375.4	829.1	1204.5	0.5433
254	402.4	376.2	828.5	1204.7	0.5475
256	403.1	376.9	828.0	1204.9	0.5517
258	403.8	377.6	827.5	1205.1	0.5559
260	404.5	378.4	826.9	1205.3	0.5601
262	405.2	379.1	826.4	1205.5	0.5642
264	405.8	379.8	825.9	1205.7	0.5684
266	406.5	380.5	825.4	1205.9	0.5726
268	407.2	381.2	824.9	1206.1	0.5767
270	407.9	381.9	824.4	1206.3	0.5809
272	408.5	382.6	823.9	1206.5	0.5850
274	409.2	383.3	823.4	1206.7	0.5892
276	409.8	384.0	822.9	1206.9	0.5934
278	410.5	384.6	822.5	1207.1	0.5976
280	411.1	385.3	822.0	1207.3	0.602
282	411.8	386.0	821.5	1207.5	0.606
284	412.4	386.6	821.1	1207.7	0.610
286	413.0	387.3	820.6	1207.9	0.614
288	413.7	388.0	820.1	1208.1	0.618
290	414.3	388.6	819.7	1208.3	0.622
292	414.9	389.3	819.2	1208.5	0.627
294	415.6	390.0	818.7	1208.7	0.631
296	416.2	390.6	818.3	1208.9	0.635
298	416.8	391.3	817.8	1209.1	0.639
300	417.4	391.9	817.4	1209.3	0.644
302	418.0	392.5	816.9	1209.4	0.648
304	418.6	393.2	816.4	1209.6	0.652
306	419.2	393.8	816.0	1209.8	0.656
308	419.8	394.4	815.6	1210.0	0.660
310	420.4	395.0	815.2	1210.2	0.664
312	421.0	395.7	814.7	1210.4	0.668
314	421.6	396.3	814.2	1210.5	0.673
316	422.2	396.9	813.8	1210.7	0.677

PROPERTIES OF SATURATED STEAM—(Continued).

Pressure above Vacuum Lbs. per Sq. Inch.	Temperature, Degrees Fahrenheit.	Heat of Liquid above 32° Fahrenheit. B. T. U.	Latent Heat above 32° Fahrenheit. B. T. U.	Total Heat above 32° Fahrenheit. B. T. U.	Density, or Weight per Cubic Foot. Pounds.
318	422.8	397.5	813.4	1210.9	0.681
320	423.4	398.1	813.0	1211.1	0.685
322	424.0	398.7	812.5	1211.2	0.690
324	424.5	399.3	812.1	1211.4	0.694
326	425.1	399.9	811.7	1211.6	0.698
328	425.7	400.5	811.3	1211.8	0.702
330	426.2	401.1	810.8	1211.9	0.707
335	427.6	402.6	809.8	1212.4	0.717
350	431.9	406.9	806.8	1213.7	0.748
375	438.4	414.2	801.5	1215.7	0.800
400	445.2	421.4	796.3	1217.7	0.853
450	456.2	433.4	787.7	1221.1	0.959
500	466.6	444.3	779.9	1224.2	1.065

AIR REQUIRED FOR VENTILATION.

Standard Parts of Carbonic Acid in 10,000 of Air in Room.	Cubic Feet of Air Required per Person.	
	Per Minute.	Per Hour.
5	133	8,000
6	67	4,000
7	44	2,667
8	33	2,020
9	27	1,600
10	22	1,333
11	19	1,151
12	17	1,000

VENTILATION FOR DIFFERENT TYPES OF BUILDINGS.

Air Supply per Occupant for	Cubic Feet per Minute.	Cubic Feet per Hour.
Hospitals	50 to 80	3,000 to 4,000
High Schools	50	3,000
Grammar Schools	40	2,400
Theatres and Assembly Halls	25	1,500
Churches	20	1,200

HORSE POWER FOR VENTILATION.

Our B. T. U. will raise the temperature of one cubic foot of air 55 degrees. In other words, the B. T. U. required to raise any given volume of air any number of degrees is equal to:

$$\frac{\text{Volume of Air in Cubic Feet} \times \text{Degrees Raised}}{55}$$

VELOCITIES OBTAINED THROUGH FLUES OF HEIGHTS FOR VARYING DIFFERENCES IN TEMPERATURE BETWEEN OUTSIDE AIR AND THAT IN FLUE.

Height of Flue in Feet.	Excess of Temperature of Air in Flue Above that of External Air.					
	5°	10°	15°	20°	30°	50°
5	55	76	94	109	134	167
10	77	108	133	153	188	242
15	94	133	162	188	230	297
20	108	153	188	217	225	342
25	121	171	210	242	297	383
30	133	188	230	265	325	419
35	143	203	248	286	351	453
40	153	217	265	306	375	484
45	162	230	282	325	398	514
50	171	242	297	342	419	541
60	188	264	325	373	461	594

NUMBER OF SQUARE FEET OF DIRECT STEAM RADIATION DIFFERENT SIZES OF PIPES WILL SUPPLY FOR VARYING LENGTHS OF RIM.

Size of Pipe.	Square Feet of Radiating Surface.								
	100 ft. Rim.	200 ft. Rim.	300 ft. Rim.	400 ft. Rim.	500 ft. Rim.	600 ft. Rim.	700 ft. Rim.	800 ft. Rim.	900 ft. Rim.
1	30	......	......	......	......	......	......	......	......
1¼	60	50	......	......	....	....	......	......	......
1½	100	75	50	......	......	......	......	......	......
2	200	150	125	100	75	......	......	......	......
2½	350	250	200	175	150	125	.....	......	......
3	550	400	300	275	250	225	200	175	150
3½	850	600	450	400	350	325	300	250	225
4	1200	850	700	600	525	475	450	400	350
5	......	1400	1150	1000	700	850	775	725	650
6	....	...	......	1600	1400	1300	1200	1150	1000
7	......	......	.....	....	......	....	1706	1606	1500

SIZES FOR VERTICAL RISERS AND DROPS FOR STEAM HEATING.

Size of Riser.	Square Feet of Radiating Surface.					
	1st Story.	2d Story.	3d Story.	4th Story.	5th Story.	6th Story.
1	30	55	65	75	85	95
1¼	60	90	110	125	140	160
1½	100	140	165	185	210	240
2	200	275	375	425	500	....
2¼	350	475	....	....	....	....
3	550	....	....	....	....	....
3½	850	....	....	....	....	....

TONNAGE BASIS IN REFRIGERATING WORK.

One ton of refrigeration is the amount of heat absorbed by the melting of 2,000 pounds of ice at 32° F. into 2,000 pounds of water at 32° F., or the amount of heat that must be extracted from 2,000 pounds of water at 32° F. to reduce it to 2,000 pounds of ice at 32° F., which is $2{,}000 \times 142 = 284{,}000$ B. T. U. The reason the multiplier 142 is used, is that the latent heat of one pound of ice is 142 B. T. U.

COMPRESSION PLANT IN REFRIGERATION

is one where the gas is drawn from the expansion side of the plant by the suction of the compressor, compressed to a liquifying pressure and discharged into the condenser.

WITH THE ABSORPTION PLANT

the gas from the expansion side is absorbed into water and a rich liquor so made is heated in a still, and the ammonia gas driven out of the water and forced into the condenser.

POWER REQUIRED FOR REFRIGERATING PLANT

is, broadly speaking, about 1.5 horse power per ton of refrigeration, for plants above 10 tons; for less tonnage about 2 horse power per ton is allowed.

TESTING AND CHARGING OF REFRIGERATING MACHINERY

as given by a prominent firm of builders, is as follows:

In testing a refrigerating plant, it is advisable to pump up an air pressure of 300 pounds per square inch. A soap suds solution should then be applied to all joints to detect any leakage. If leaks are discovered, the air must be allowed to escape and such new gaskets inserted or such new joints made, as circumstances demand.

After the entire plant has been carefully examined and found absolutely tight, a pressure of 300 pounds should be maintained and the compressor permitted to remain idle for a period of about twelve hours. Unless there is further leakage or a severe fluctuation in atmospheric temperature, this pressure will remain constant. When such a condition is assured, it is advisable to admit a small quantity of ammonia into the system. For instance, a 10-ton plant would require about 15 pounds, a 25-ton plant, about 30 pounds, a 50-ton plant, about 60 pounds by weight and for a 100-ton plant, about one cylinder of ammonia should be used.

A pressure of about 300 pounds per square inch should then be pumped up, and in the event of further leakage in any part of the plant, it will readily be detected because of the obnoxious odor of ammonia gas.

Several methods of detecting ammonia leaks are employed, among which are the use of litmus paper, usually supplied by manufacturers of ammonia, and also by the use of sulphur sticks. White litmus paper slightly moistened

will turn red in the presence of ammonia fumes. Lighted sulphur sticks, when brought into contact with the ammonia fumes will create a very black smoke. This is one of the most positive methods known. After the plant has been tested in this manner, all compressed air should be allowed to escape down to the atmospheric pressure, after which the machine should be started and the coils evacuated of any remaining air, until there exists a vacuum of from 28 to 29 inches.

The machine should again be permitted to stand inactive for a period of from six to eight hours for the purpose of determining whether the piping and joints are absolutely tight against the external pressure of the atmosphere. If the system is tight, the vacuum will remain constant. Should the vacuum be broken, it will indicate the presence of a leak, which should be definitely located.

After the plant has been finally tested with both air pressure and vacuum, the system should be pumped down to about 28 or 29 inches and the ammonia drums connected. The ammonia should be permitted to run into the low pressure side until a pressure of 10 or 15 pounds is secured. The condensing water must then be supplied to ammonia condenser and the machine operated for the purpose of confining the ammonia to the condenser and liquid receiver. When pumping the ammonia into the system, we advise that the pressure on the low pressure side of the machine never be decreased to the extent of less than 5 pounds, as the small quantity of ammonia then remaining in the ammonia drum would not justify the expense of pumping down to a 10 or 15-inch vacuum as is frequently done for the purpose of securing a complete evacuation of the drum. This is also a doubtful method of charging the machine, owing to the liability of admitting considerable air through the stuffing box packing on the piston rod, when working the machine under a vacuum. This of course, would create a false condensing pressure, which would necessitate the interruption of the machine for the purpose of purging the system.

PROPERTIES OF SATURATED AMMONIA GAS.

Gauge Pressure Pounds per Square Inch.	Absolute Pressure, Pounds per Square Inch.	Temperature Degrees F.	Absolute Temperature Degrees Fahrenheit.	Latent Heat of Evaporation in Thermal Units.	Volume of One Pound Vapor in Cubic Feet.	Weight of One Cubic Foot of Vapor in pounds.	Volume of One Pound of Liquid in Cubic Feet.	Weight of One Cubic Foot of Liquid in pounds.
—4.01	10.69	—40	420.66	579.67	24.38	.0410	.0234	42.589
—2.39	12.31	—35	425.66	576.68	21.32	.0469	.0236	42.337
—0.57	14.13	—30	430.66	573.69	18.69	.0535	.0237	42.123
+1.47	16.17	—25	435.66	570.68	16.44	.0608	.0238	41.858
3.75	18.45	—20	440.66	567.67	14.51	.0690	.0240	41.615
6.29	20.99	—15	445.66	564.64	12.83	.0779	.0241	41.374
9.10	23.80	—10	450.66	561.61	11.38	.0878	.0243	41.135
12.22	26.92	— 5	455.66	558.56	10.12	.0988	.0244	40.900
15.67	30.37	0	460.66	555.50	9.03	.1107	.0246	40.650
19.46	34.16	+ 5	465.66	552.43	8.07	.1240	.0247	40.404
23.64	38.34	10	470.66	549.35	7.23	.1383	.0249	40.160
28.24	42.94	15	475.66	546.26	6.49	.1541	.0250	39.920
33.25	47.95	20	480.66	543.15	5.84	.1711	.0252	39.682
38.73	53.43	25	485.66	540.03	5.27	.1897	.0253	39.432
44.72	59.42	30	490.66	536.91	4.76	.2099	.0255	39.200
51.22	65.92	35	495.66	533.78	4.31	.2318	.0256	38.940
58.29	72.99	40	500.66	530.63	3.91	.2554	.0258	38.684
65.96	80.66	45	505.66	527.47	3.56	.2809	.0260	38.461
74.26	88.96	50	510.66	524.30	3.24	.3084	.0261	38.226
83.22	97.92	55	515.66	521.12	2.96	.3380	.0263	37.994
92.89	107.59	60	520.66	517.93	2.70	.3697	.0265	37.736
103.33	118.03	65	525.66	514.73	2.48	.4039	.0266	37.481
114.49	129.19	70	530.66	511.52	2.27	.4401	.0260	37.230
126.52	141.22	75	535.66	508.29	2.09	.4791	.0270	36.995
139.40	154.10	80	540.66	505.05	1.92	.5205	.0272	36.751
153.18	167.88	85	545.66	501.81	1.77	.5649	.0273	36.509
167.92	182.62	90	550.66	498.55	1.64	.6120	.0275	36.258
183.65	198.35	95	555.66	495.29	1.51	.6622	.0277	36.023
200.42	215.12	100	560.66	492.01	1.39	.7153	.0279	35.778
218.28	232.98	105	565.66	488.72	1.289	.7757	.0281	....
237.27	251.97	110	570.66	485.42	1.203	.8312	.0283	....
258.7	272.14	115	575.66	482.41	1.121	.8912	.0285	....
275.79	293.49	120	580.66	478.79	1.041	.9608	.0287	....
301.46	316.16	125	585.66	475.45	.9699	1.0310	.0289	....
325.72	340.42	130	590.66	472.11	.9051	1.1048	.0291	....
350.46	365.16	135	595.66	468.75	.8457	1.1824	.0293	....
377.52	392.22	140	600.66	465.39	.7910	1.2642	.0295	....
405.79	420.49	145	605.66	462.01	.7408	1.3497	.0297	....
435.5	450.20	150	610.66	458.62	.6946	1.4396	.0299	....
466.84	481.54	155	615.66	455.22	.6511	1.5358	.0302	....
499.70	514.50	160	620.66	451.81	.6128	1.6318	.0304	....
534.34	549.04	165	625.66	448.39	.5765	1.7344	.0306	....

One atmosphere in this table is equal to a pressure of a column of mercury. 29.9 inches high.

Specific heat of ammonia gas and vapor at constant pressure = 0.508
The same at constant volume .... = 0.3913
Weight of 1 cubic foot liquid ammonia at 32 degrees Fahr. =39.108 Lbs.
Volume of 1 pound liquid ammonia at 32 degrees Fahr.... = 0.02557 cu.ft.
Specific heat of liquid ammonia .... = 1.01235 + 0.008378 t.[2]

TABLE OF BRINE SOLUTION.

(CHLORIDE OF SODIUM—COMMON SALTS.)

Percentage of Salt by Weight.	Degrees on Salometer at 60 Degrees F.	Specific Gravity at 60 Degrees Fahr.	Specific Heat.	Weight of 1 Gallon.	Pounds of Salt in 1 Gallon.	Pounds of Water in 1 Gallon.	Weight of 1 Cubic Foot.	Pounds of Salt in 1 Cubic Foot.	Pounds of Water in 1 Cubic Foot.	Freezing Point, Degrees Fah.
0	0	1.	1.	8.35	0.	8.35	62.4	0.	62.4	32.
1	4	1.007	0.992	8.4	0.084	8.316	62.8	0.628	62.172	31.8
5	20	1.037	0.96	8.65	0.432	8.218	64.7	3.237	61.465	25.4
10	40	1.073	0.892	8.95	0.895	8.055	66.95	6.695	60.253	18.6
15	60	1.115	0.855	9.3	1.395	7.905	69.57	10.435	59.134	12.2
20	80	1.150	0.829	9.6	1.92	7.68	71.76	14.352	57.408	6.86
25	100	1.191	0.783	9.94	2.485	7.455	74.26	18.565	55.695	1.00

TABLE OF CHLORIDE OF CALCIUM SOLUTION.

Specific Gravity at 64 Degrees Fah.	Degree Beaume at 64 Degrees Fah.	Degree Salometer at 64 Degrees Fahrenheit.	Per Cent of $CaCl_2$.	Freezing Point in Degrees Fah.	Ammonia Gauge Pressure Pounds per Square Inch.
1.007	1	4	0.943	+31.20	46
1.014	2	8	1.886	+30.40	45
1.021	3	12	2.829	+29.60	44
1.028	4	16	3.772	+28.80	43
1.035	5	20	4.715	+28.00	42
1.043	7	24	5.658	+26.89	41
1.050	7	28	6.601	+25.78	40
1.058	8	32	7.544	+24.67	38
1.065	9	36	8.487	+23.56	37
1.073	10	40	9.430	+22.09	35.5
1.081	11	44	10.373	+20.62	34
1.089	12	48	11.316	+19.14	32.5
1.097	13	52	12.259	+17.67	30.5
1.105	14	56	13.202	+15.75	29
1.114	15	60	14.145	+13.82	27
1.122	16	64	15.088	+11.89	25
1.131	17	68	16.031	+ 9.96	23.5
1.140	18	72	16.974	+ 7.68	21.5
1.149	19	76	17.917	+ 5.40	20
1.158	20	80	18.860	+ 3.12	18
1.167	21	84	19.803	— 0.84	15
1.176	22	88	20.746	— 4.44	12.5
1.186	23	92	21.689	— 8.03	10.5
1.196	24	96	22.632	—11.63	8
1.205	25	100	23.575	—15.23	6
1.215	26	104	24.518	—19.56	4
1.225	27	108	25.461	—24.43	1.5
1.236	28	112	26.404	—29.29	1'' vacuum
1.246	29	116	27.347	—35.30	5'' vacuum
1.257	30	120	28.290	— 41.32	8.5'' vacuum
1.268	31	....	29.233	—47.66	12'' vacuum
1.279	32	....	30.176	—54.00	15'' vacuum
1.290	33	....	31.119	—44.32	10'' vacuum
1.302	34	....	32.062	—34.66	4'' vacuum
1.313	35	....	33.	—25.00	1.5 pounds

REFRIGERATING EFFECT OF ONE CUBIC FOOT OF AMMONIA GAS AT DIFFERENT CONDENSER AND SUCTION (BACK) PRESSURES IN B. T. U.

Temperature of Gas in Degrees Fah.	Corresponding Suction Pressure Pounds per Sq. Inch.	Temperature of the Liquid in Degrees Fahrenheit.								
		65°	70°	75°	80°	85°	90°	95°	100°	105°
		Corresponding Condenser Pressure (gauge), Pounds per Square Inch.								
		103	115	127	139	153	168	184	200	218
	G.Pres.									
—27°	1	27.30	27 01	26.73	26.44	26.16	25.87	25.59	25.30	25.02
—20°	4	33.74	33.40	33.04	32.70	32.34	31.99	31.64	31.30	30.94
—15°	6	36.36	36.48	36.10	35.72	35.34	34.96	34.58	34.20	33.82
—10°	9	42.28	41.84	41.41	40.97	40.54	40.10	39.67	39.23	38.80
— 5°	13	48.31	47.81	47.32	46.82	46.33	45.83	45.34	44.84	44.35
0°	16	54.88	54.32	53.76	53.20	52.64	52.08	51.52	50.96	50.40
5°	20	61.50	60.87	60.25	59.62	59.00	58.37	57.75	57.12	56.50
10°	24	68.66	67.97	67.27	66.58	65.88	65.19	64.49	63.80	63.16
15°	28	75.88	75.12	74.35	73.59	72.82	72.06	71.29	70.53	69.70
20°	33	85.15	84.30	83.44	82.59	81.73	80.88	80.02	79.17	78.31
25°	39	95.50	94.54	93.59	92.63	91.68	90.72	89.97	88.81	87.86
30°	45	106.21	105.15	104.09	103.03	101.97	100.91	99.85	98.79	97.73
35°	51	115.69	114.54	123.39	112.24	111.09	109.94	108.79	107.64	106.49

NUMBER OF CUBIC FEET OF GAS THAT MUST BE PUMPED PER MINUTE AT DIFFERENT CONDENSER AND SUCTION PRESSURES TO PRODUCE ONE TON OF REFRIGERATION IN TWENTY-FOUR HOURS.

Temperature of Gas in Degrees Fah.	Corresponding Suction Pressure Pounds per Sq. Inch.	Temperature of the Gas in Degrees Fahrenheit.								
		65°	70°	75°	80°	85°	90°	95	100°	105°
		Corresponding Condenser Pressure (gauge), Pounds per Square Inch.								
		103	115	127	139	153	168	184	200	218
	G. Pres									
—27°	1	7.22	7.3	7.37	7.46	7.54	7.62	7.70	7.79	7.88
—20°	4	5.84	5.9	5.96	6.03	6.09	6.16	6.23	6.30	6.43
—15°	6	5.35	5.4	5.46	5.52	5.58	5.64	5.70	5.77	5.83
—10°	9	4.66	4.73	4.76	4.81	4.86	4.91	4.97	5.05	5.08
— 5°	13	4.09	4.12	4.17	4.21	4.25	4.30	4.35	4.40	4.44
0°	16	3.59	3.63	3.66	3.70	3.74	3.78	3.83	3.87	3.91
5°	20	3.20	3.24	3.27	3.30	3.34	3.38	3.41	3.45	3.49
10°	24	2.87	2.9	2.93	2.96	2.99	3.02	3.06	3.09	3.12
15°	28	2.59	2.61	2.65	2.68	2.71	2.73	2.76	2.80	2.82
20°	33	2.31	2.34	2.36	2.38	2.41	2.44	2.46	2.49	2.51
25°	39	2.06	2.08	2.10	2.12	2.15	2.17	2.20	2.22	2.24
30°	45	1.85	1.87	1.89	1.91	1.93	1.95	1.97	2.00	2.01
35°	51	1.70	1.72	1.74	1.76	1.77	1.79	1.81	1.83	1.85

DAILY ELEVATOR REPORT*

Date________________ Monroe Street

Mach. No.	In Service	Out of Service	What Repair	Time Off	REMARKS
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

SUPPLIES WANTED..

....

....

....

....

SIGNED..

* Working size of this sheet 8x14.

ENGINE No. 1.* Month of.................. ....190...

Date	Hours Run	Cy'l Oil	K W. Hours	Elec. P. Hours	Remarks and Repairs

* Working size of this sheet 12x16

SWITCHBOARD READINGS*

Date

	DYNAMO NO. 1		DYNAMO NO. 2		DYNAMO NO. 3		DYNAMO NO. 4		DYNAMO NO. 5		REMARKS
	AM.	Volts	AM.	Volts	AM.	Volts	AM.	Volts	AM.	Volts	
1 A. M.											
2 "											
3 "											
4 "											
5 "											
6 "											
7 "											
8 "											
9 "											
10 "											
11 "											
12 "											
1 P. M.											
2 "											
3 "											
4 "											
5 "											
6 "											
7 "											
8 "											
9 "											
10 "											
11 "											
12 "											

TOTAL AM........................AVERAGE AM. HRS..................................

TOTAL K. W....................READING TOTAL WATT METER....... ....

AVERAGE VOLTAGE..........................

*Working size of this sheet 9x13.

DAILY BOILER ROOM REPORT*

Date________________________________

EQUIPMENT	ON	OFF	DAYS RUN	WHEN WASHED	CONDITION Int.	CONDITION Ext.	DRAFT IN.	REMARKS AND REPAIRS
Boiler No. 1...								
Boiler No. 2...								
Boiler No. 3...								
Boiler No. 4...								
Boiler No. 5...								

STOKERS						REMARKS AND REPAIRS
No. 1........						
No. 2........						
No. 3........						
No. 4........						
No. 5........						

STOKER FANS	ON	OFF	HOURS RUN	CON-DITION	CYL. OIL PTS.	MACH. OIL PTS.	REMARKS AND REPAIRS
Engine.......							
Motor........							

WEBSTER HEATERS	IN	OUT	DAYS RUN	CON-DITION	WHEN CLEANED	Compound Pounds	REMARKS AND REPAIRS
No. 1........							
No. 2........							

SAFETY VALVES	WHEN TESTED	BLOWS AT PRESS	CON-DITION	REMARKS AND REPAIRS
No. 1........				
No. 2........				
No. 3........				
No. 4........				
No. 5				

NO. OF LOADS OF ASH REMOVED........	....	....
CARS OF COAL BURNED..........	....	SUPPLIES WANTED........................
CARS OF ASH REMOVED..........	....	....
LOADS OF COAL RECEIVED.......	....	GENERAL REMARKS........................
WEIGHT OF COAL BURNED.......	....	
WEIGHT OF ASH....................	....	

FROM............TO.............. SIGNED..................................ENGINEER

*Working size of this sheet 12x16.

DAILY ENGINE ROOM REPORT*

Date.................... O. L....................

EQUIPMENT	STARTED	STOPPED	Hours Run	Cylinder Oil Pts.	REMARKS AND REPAIRS
Engine No. 1..					
Engine No. 2..					
Engine No. 3..					
Engine No. 4..					
Engine No. 5..					

ELEVATOR PUMPS	STARTED	STOPPED	Hours Run	Cylinder Oil Pts.	REMARKS AND REPAIRS
Pump No. 1 ...					
Pump No. 2 ...					
Pump No. 3 ...					
Pump No. 4 ...					

ELEVATOR Auxiliaries	STARTED	STOPPED	Hours Run	Cylinder Oil Pts.	REMARKS AND REPAIRS
Pump No. 1 ...					
Pump No. 2 ...					

REFRIGERAT'G	STARTED	STOPPED	Hours Run	Condenser Press	Back Press.	Tempt. D. W.	Tempt Brine	Am. Ht. in Glass	REMARKS AND REPAIRS
Comp'r No. 1..									

BOILER FEED PUMPS	STARTED	STOPPED	Hours Run	Tempt. Feed Wat'r	Cyl. Oil Pts.	
Pump No. 1 ...						
Pump No. 2 ...						

FILTER	WHEN WASHED	Condition	

HEATING SYSTEM		EXHAUST	LIVE STEAM	Exp. Tank Pr's	Vacu'm In	Pump No. 1	Started	Stopped	Hrs. Run	Cyl. Oil Pts.	Live Stm Hrs.	Court Risers		Main North		Main South		First Floor	
On	Off					Pump No. 2	Started	Stopped	Hrs. Run			On	Off	On	Off	On	Off	On	Off

GENERAL REMARKS..

....

SIGNED.......................................ENGINEER

FROM ....TO..........................

*Working size of this sheet 12x16.

TROUBLE TICKET.*

DATE

ROOM NO.

TIME REC'D A. M. P. M.

NATURE OF TROUBLE

MATERIAL USED

TIME O. K.		TIME PUT IN	REPAIRED BY
A. M.	P. M.		

RECEIVED BY PHONE OFFICE

*Working size of this sheet 6 x 9

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